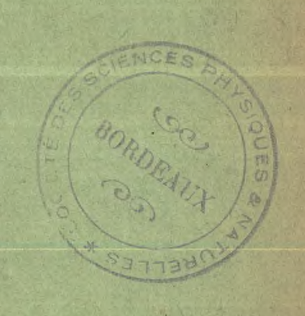
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TOME XXXVI

(FASCICULE 1)

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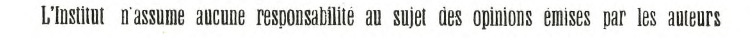


LE CAIRE
IMPRIMERIE DE L'INSTITUT FRANÇAIS
D'ARCHÉOLOGIE ORIENTALE
1955

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1955

MAGNETIC OBSERVATIONS IN THE SOUDAN

JANUARY TO FEBRUARY 1952 [1]

BY

M. R. MADWAR

During the meeting of the International Union of Geodesy and Geophysics at Oslo in 1948, the International Association of terrestrial magnetism and electricity endorsed resolution no. 14 adopted at the Brussels meeting of the mixed commission on the Ionosphere of the International council of Scientific Union namely :

« That in view of the remarkable geomagnetic control of F_2 layer density and the known abnormal variation of daily magnetic force in regions where the geomagnetic and geographical equators are widely separated, efforts should be made to achieve operation for one or two years of a chain of ionospheric and magnetic stations across these equators near the longitude of Huancayo or in East Africa and if possible another chain near a place at which these equators coincide».

To carry out in effect this resolution observations are primarily required for the daily variation of horizontal magnetic component of the earth's field at a series of stations about 150 km. apart lying in along an approximate N-S. line outside and between the geographical and magnetic equator.

Dr. A. G. McNish [2] has given the results from an analysis of the diurnal variations of magnetic elements for five observatories in the western hemisphere, and he points that the establishment of a magnetic observatory at Huancayo Peru (latitude 12.0°; longitude 284.7°) is almost at the magnetic equator in 1922, has led to the discovery of magnetic diurnal variation markedly different from those expected in such a

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[1] Communication présentée en séance du 2 novembre 1953.

[2] McNish A. G., *Transactions of the Ass. of terrestrial magnetism,* p. 271 (1937).

region. And from analysis of observations of the total range in the diurnal variation of H. Dr. J. Edegal[1] pointed out that at five stations distributed on and near magnetic equator North and South of it; there is a great increase in the range of H in narrow zone near the equator which indicates that the variation is caused by a varying electric current in a very narrow zone of the atmosphere above the magnetic equator.

It appeared obvious to the members of the Committee formed for the study of diurnal magnetic observations in equatorial regions, that more observations are needed at the magnetic equator, as well as at places where the distance between magnetic and geographic equator is greatest, as near the places where the two equators are crossing each other.

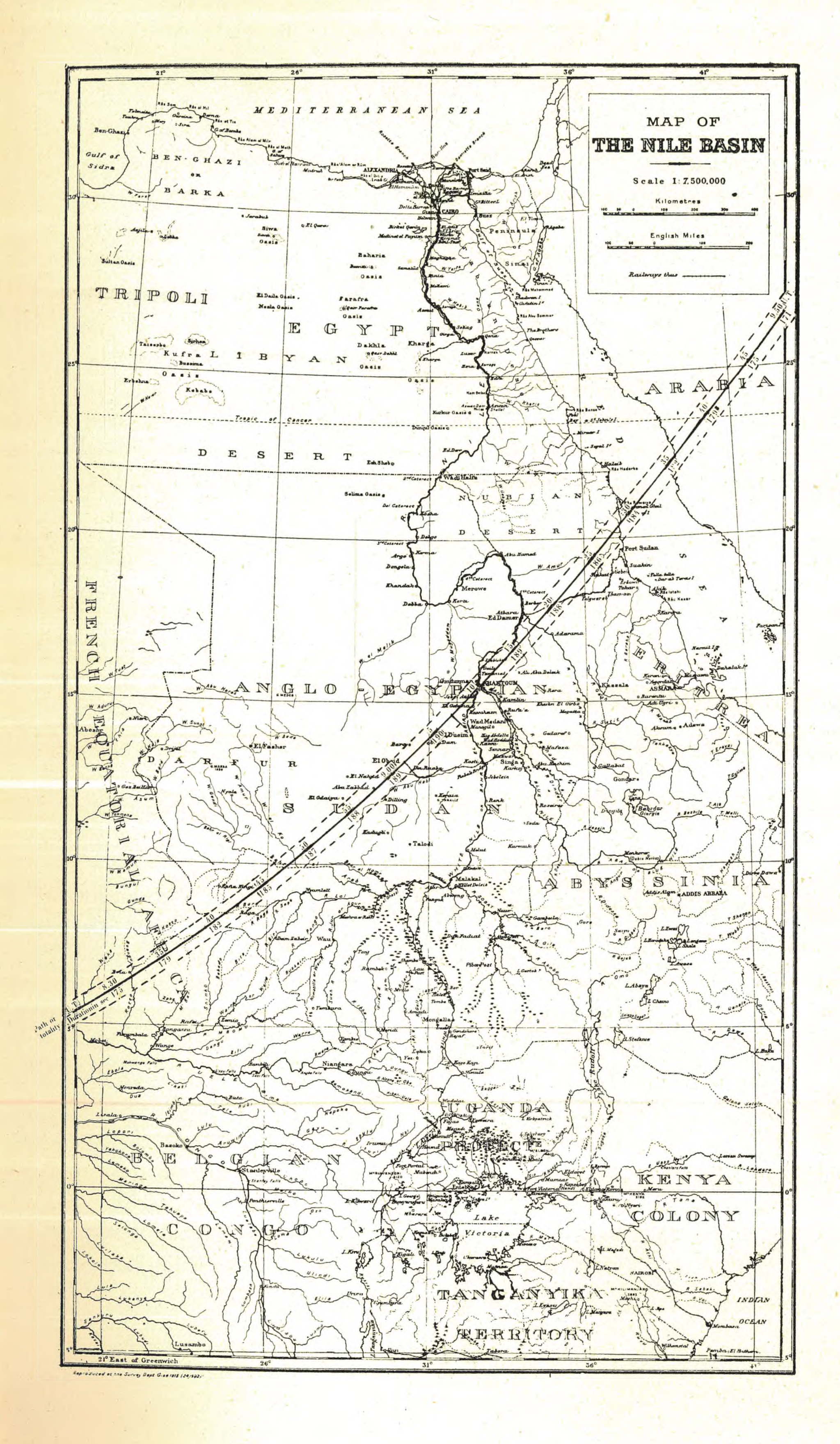
For this purpose members of the committee has been active. Professor Coulomb has arranged observations in Togoland, Father Romàná in the Gulf of Giunea, Dr. Giesecke in South America, Dr. Banerji in India, during 1948-1951, and I have taken advantage of the fact that the senate of the University of Cairo has sanctioned an Egyptian expedition to observe the total eclipse of the sun on the 25th February 1952, to carry out magnetic observations during January and first week of February nearly along the 30th meridian, from Juba to Khartoum, and in Waw, Bahr El Ghasal region and at a point where magnetic equator crosses the path of totality on the 25th February. M. Mathews of the Soudan Meteorological was trained to carry out these observations during the eclipse day, before and after, at Kubbo ($\varphi = 10° 7.3$ N. and λ $26° 37.0$ E.).

The instrument used for this purpose is the QHM La Cour, a theodolite was mounted on the base, in order to determine the magnetic declination as well.

The observations were made at sunrise (6h.-7h.), just before noon (11h.-12h.) and at sunset (17h.-18h.) three complete observations were made each time, and for 2-3 days at each station occupied.

The quartz-horizontal force magnetometer (QHM) consists essentially of a small magnet suspended by quartz thread, and has a mirror

[1] Edegal J., *Terrestrial magnetism*, vol. 52, n° 4, p. 449, 1947.



at one end perpendicular to its axis. A telescope attached to verniers reading a horizontal devided circle can be turned until views its own crosswires by reflection from the mirror, and so it is possible to record angles through which the magnet turns.

The magnet is first adjusted so that it can be close to the magnetic meridian making with it a small unknown angle α so that

$$mH \sin \alpha = \tau \psi$$

where ψ is the twist in the quartz suspension and τ is a constant. The telescope and point of suspension, but not the magnet are then turned through 360° plus an angle α_1, to give equilibrum and thus

$$mH \sin (\alpha_1 + \alpha) = \tau (\psi + 2\pi)$$

and although the telescope turns through an angle $360 + \alpha$, the additional twist in the suspension is exactly 360° because the magnet turns through α_1, the telescope is then turned back about two whole turns to give equilibrum at a reading $\alpha - \alpha_2$ where

$$mH \sin (\alpha - \alpha_2) = \tau (\psi - 2\pi)$$

From these equations :

$$H = (4 \pi \tau / m) \div \{\sin (\alpha + \alpha_1) - \sin (\alpha - \alpha_2)\}$$

$$\div \frac{2 \pi \tau}{m \sin \varphi} \qquad \text{where } \varphi = \tfrac{1}{2}(\alpha_1 + \alpha_2).$$

The cœfficient of torsion τ, of the fibre depends on the temperature and magnetic moment m of the magnet depends on both temperature and induction. To correct for these the formula is modified to read :

$$\log H = C - \log \sin \alpha + c_1.t - \mu H \cos$$

where t is the temperature in (°C.), c_1 is a constant depending on the temperature cœfficient of torsion and magnetic moment, and μ the cœfficient of induction; C is a calibration constant.

The instrument is simple, observations are rapid and so highly accurate, that the instrument has been used for geophysical explorations :

Reduction of observations : The observations are carried out during the period in which the maxima and minima of the daily variation occur.

The range is determined between the highest value of H which occurs at or near local noon and the lowest value of H which occur at or about sunrise or sunset. The observed range has to be corrected for sun spot number, declination of the sun and moon. In 1952 the sun spot number may be near the mean sun spot number and therefore the corrected ranges—may be considered to correspond to mean sun-spot number. Then the mean range for each station has to be corrected for lunar and annual variation, and reduced to Huancayo Observatory mean range of 115 γ for the two years period of 1923 to 1933 and from the monthly ranges of the ten least disturbed days, the mean values for each month has been computed and the values have been smoothed in using the sum of the values of the annual and semi-annual harmonic terms.

The following table gives the calculated mean monthly values for Huancayo :

January 111	April 103	July 92	October 126
February 129	May 107	August 111	November ... 113
March 140	June 89	Sept. 127	Decembre ... 104

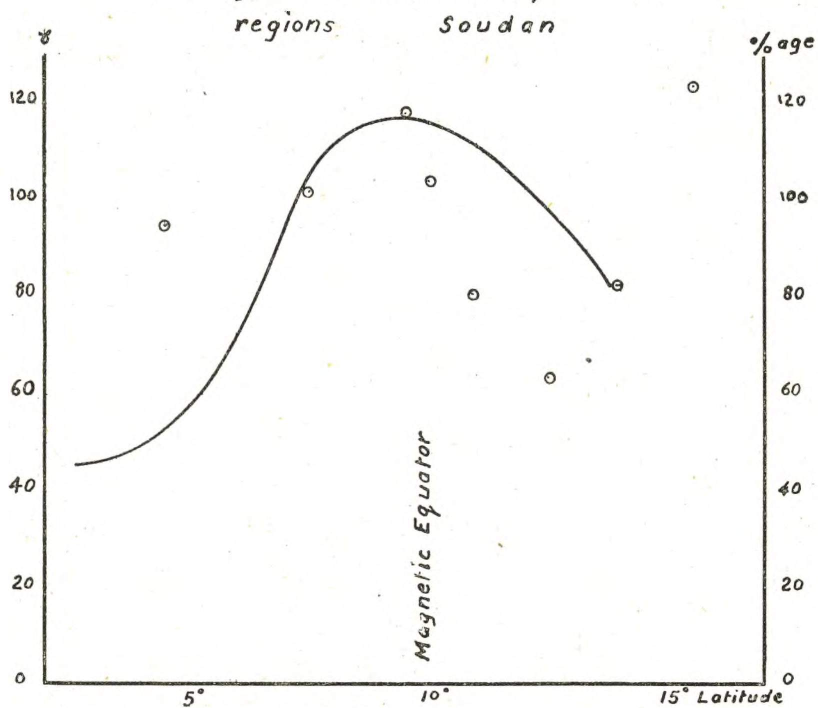
The annual variation of the range of the daily variation in H may be expected to be nearly equal to a variation like that of Huancayo but displaced by six months.

The daily variation of the range of H with the age of the moon has also been determined by M. Pontier for the Huancayo Observatory for sun spot maximums; the following table :

Age of the moon	Correction %	Age of the moon	Correction %	Age of the moon	Correction %
0	− 7	10	+ 11	20	− 1
1	− 9	11	+ 8	21	+ 4
2	− 9	12	+ 4	22	+ 8
3	− 8	13	− 1	23	+ 11
4	− 6	14	− 5	24	+ 11
5	− 2	15	− 8	25	+ 10
6	+ 2	16	− 9	26	+ 7
7	+ 7	17	− 9	27	+ 3
8	+ 10	18	− 8	28	− 2
9	+ 11	19	− 5	29	− 6

These corrections are valid only for Huancayo, and possibly further stations; only an insignificant error would arise if the above corrections were applied to data from all considered stations.

The following table «I» gives the observed values of H and declination at all stations considered. Table II gives the range of mean values for all days and the various correctings applied to give corrected range and its % in terms of the Huancayo mean value of 115.



From the curve it appears that there seems to be a slight displacement of the maximum towards the geographic equator and there is no doubt that maximum range occur at the magnetic equator long the 30th meridian. (Observations at Malakal on two quite days).

Acknowledgement is here made to the Egyptian Irrigation Department in Soudan, for transportation facilities, to Dr. Edegal, president of the Committee for 200 dollars grant, to pay part of the transportation cost and Dr. A. A. Giesecke for valuable assistance.

Table I

RESULTS OF MAGNETIC OBSERVATIONS
in Equatorial Regions.

Date	Time	Horizontal Component	Declination West (Mean of 3 Observ.)	Remarks
	h m	γ		
Khartoum Lat. 15°36'.2		Long. 32°33'0		
10-1-1952	6 48	35465		
	7 04	473		
	7 16	480		
	12 16	487		
	12 32	466		small dist.
	12 50	482		
	17 54	415		
	18 09	409	41'.6	
11-1-1952	6 33	469		
	6 52	468	38'.7	
	7 08	468		
	11 17	505		
	33	499	41'.9	Disturbance
	50	500		
	18 40	368		
	54	365	41'.4	
	19 06	376		
Dueim. Lat. 13°59'.0		Long. 32°18.8		
6-2-1952	7 04	35593		
	20	597	49'.5	
	31	598		
	11 09	552		
	19	546	45'.4	Severe Storm
	28	559		
	17 09	474		
	17	480	46'.3	
	28	480		
7-2-1952	6 29	465		
	37	455	43'.8	
	46	459		
	58	465		
	11 48	457		
	56	461	42'.2	Severe Storm
	12 03	449		
	17 16	462		
	25	427	44'.6	
	35	453		

Date	Time	Horizontal Component	Declination West (Mean of 3 Observ.)	Remarks
	h m	γ		
Gebellin Lat. 12°35.8		Long. 32°48.5		
2-2-1952	6 39	35383		
	48	381	1° 3.2	
	55	383		
	11 32	434	1° 2.5	Quiet
	41	422		
	51	421		
	17 24	346		
	50	360	0° 59.3	
3-2-1952	6 23	383		
	31	381	1° 2.2	
	41	379		
	11 15	413		
	23	420	1° 1.3	Quiet
	34	415		
	17 12	35397		
	22	391	1° 1.5′	
	28	390		
Meitimer Lat. 10°59.5		Long. 32°38.5		
30-1-1952	6 29	35298		
	46	307		
	57	317		
	11 09	341		
	30	349	1° 14.8	Quiet
	43	345		
	17 51	336		
	18 08	321	1° 16.0	
31-1-1952	6 24	344		
	34	343	1° 20.4	
	44	339		
	11 21	447		
	31	451	1° 15.2	Disturbance in the afternoon
	42	448		
	17 16	323		
	26	353	1° 15.0	
	38	328		
Kubbo Lat. 10°07.3		Long. 26°37.0		
23-2-1952	17 22	34597		
	36	597	2° 11.7	Quiet
	47	599		
24-2-1952	6 42	479		
	54	487	2° 6.5	
	7 08	506		

Date	Time	Horizontal Component	Declination West (Mean of 3 Observ.)	Remarks
	h m	γ		
24-2-1952	7 19	34509		
	11 01	635		
	12	616	2° 9′.6	Disturbed
Eclipse station	28	584		
	40	620		
	16 56	498		
	17 06	493	2° 12′.4	
	16	491		
	25	497		
25-2-1952	6 38	34529		
	46	531	2° 10′.5	
	54	535		
	7 02	537		
	9 38	604	2° 9′.0	
	46	607	9′.1	
	57	605	9′.4	
	10 08	600	9′.6	quiet except a deep bay from 13 h to 15 h.
	18	595	9′.8	
	28	588	11′.5	
	37	577	11′.7	
	48	582	11′.4	
	59	587	11′.5	
	11 08	592	11′.7	
	17	587	11′.1	
	28	573	11′.1	
	36	573	10′.7	
	50	568	11′.1	
	12 04	564	11′.0	
	14	561	10′.7	
	23	564	10′.6	
	17 34	545		
	40	557		
	48	555	2° 11′.7	
	55	556		
26-2-1952	6 30	562		
	39	566		
	47	566	2° 10′.1	
	56	574		disturbed
	10 58	671		
	11 07	676		
	16	671	2° 9′.3	
	28	651		

Date	Time	Horizontal Component	Declination West (Mean of 3 Observ.)	Remarks
	h m	γ		
Malakal Lat. 9°33.5		Long. 31°38.5		
19-1-1952	6 36	34932		
	7 02	937	1° 49'.2	
	12 25	35036		Quiet
	39	029		
	19 59	34936		
	18 37	945	1° 48'.9	
20-1-1952	6 24	929		
	34	936	1° 50'.2	
	43	942		
	11 20	35029		
	28	027	1° 46'.9	Quiet
	38	024		
	17 30	34945		
	44	942		
	18 01	924		
Waw. Lat. 7°31.0		Long. 27°59.0		
23-1-1952	7 03	34340		
	19	334		
	30	344		
	11 23	437		
	36	431	2° 42'.3	Small dist.
	47	440		
	17 40	364		
	50	351	2° 35'.5	
	18 03	352		
24-1-1952	6 32	355		
	40	360	2° 45'.3	
	53	359		
	11 21	394		
	30	394	2° 4'.1	disturbed
	38	391		
	17 33	348		
	42	343	2° 39'.4	
	50	332		
	18 02	330		
25-1-1952	6 44	369		
	56	369	2° 44'.3	
	7 03	377		
	11 47	447		
	56	448	2° 41'.4	
	12 06	450		
	17 39	358		

Date	Time	Horizontal Component	Declination West (Mean of 3 Observ.)	Remarks
	h m	γ		
25-1-1952	17 49	34357		
	58	351		
	18 07	355		
Juba. Lat. 4°52.0		Long. 31°56.25		
15-1-1952	6 31	33704		
	47	689		
	57	690		
	7 12	693		
	11 47	734		Great dist.
	12 19	734		from 15 h to 23 h.
	17 27	592		
	40	593	2° 27.8	
	49	592		
16-1-1952	6 20	703		
	33	695	2° 22'.7	
	45	702		
	10 52	732		
	11 04	736	2° 25'.6	
	12 16	730		Quiet
	17 53	714		
	18 03	720	2° 25'.3	
	17	721		
17-1-1952	7 02	690		
	13	695	2° 38'.2	
	21	693		
	11 41	752		
	53	743	2° 45'.2	Quiet
	17 51	681		
	18 04	675	2° 9'.1*	
	33	678		

The times given are for the 30th meridian Egyptian Civil Time (E. C. T.)

TABLE II

REDUCTION OF OBSERVATIONS

Latitude	Date	Range Mean Values	Mean	Moon's Age days	Corr. %	Ratio (Ann. var.)	Corr. %	Corr. Range	% of Corr. Range
15°36'.2	10/1 11/1	70 130	100	13.	− 1	$\frac{115}{92}$	+25	124	1.08
13°59'.0	6/2 7/2	69	69	10.1	+11	$\frac{115}{105}$	+10	83	0.72

* Probably due to a wrong reading of the circle.

Latitude	Date	Range Mean Values	Mean	Moon's Age days	Corr. °/o	Ratio (Ann. var.)	Corr. °/o	Corr. Range	°/o of Corr. Range
12°35'.8	2/2 3/2	73 37	55	6.6	+ 5	$\frac{115}{103}$	+12	64	0.56
10°59'.5	30/1 31/1	39 114	76	3.6	− 7	$\frac{115}{101}$	+14	81	0.70
10°07'.3	24/2 23/2 26/2	121 — 102	112	28.1 0.6	− 2 − 8	$\frac{115}{116}$	− 1	117 (105) 93	0.91
9°33'.5	19/1 20/1	92 91	92	22	+ 8	$\frac{115}{95}$	+21	119	1.04
7°31'.0	23/1 24/1 25/1	99 56 91	82	26.5	+ 5	$\frac{115}{97}$	+19	102	0.89
4°52'.0	15/1 16/1 17/1	138 34 67	80	18.5	− 6	$\frac{115}{92}$	+92	95	0.83

ERRATUM

P. 8, à la fin du 4e paragraphe, *lire*, formule corrigée :

$$\log H = C - \log \sin \varphi + c_1 . t - \mu H \cos \varphi .$$

SOME COMPLEX FEATURES OF THE EPIDIORITE OF WADI MUBARAK [1]

BY

M. S. AMIN M. SC., PH. D. (LONDON)

AND

M. L. A. KABESH B. SC.

Abstract

The epidiorite mass of Wadi Mubarak presents some complex features as relics of fresh epidiorite, association with paraschists and granitic invasions and development of schistose belts.

I. Introduction

During 1951-1952, the Geological Survey mapped a huge mass of epidiorite along Wadi Mubarak in the north-eastern sector of the Nab'a, District (Barramiyia-East Sheet, Eastern Desert of Egypt). This epidiorite mass, same as other masses nearby, shows some complex features which are described in this article. The epidiorite mass examined lies along Wadi Mubarak in the area shown in fig. 1 which extends for some two kilometres along the Wadi and of which a sketch geological map is given in fig. 2.

II. General Geology

The epidiorite mass of Wadi Mubarak is of wide extension. It is bordered on the N. W. by the metamorphic paraschists which, according

[1] Communication présentée en séance du 3 mai 1954.

to the Geological Survey Memoir, are of older age. The epidiorite mass extends southwards and south-westwards where it is bordered by the younger grey and yellow granites of the Nab'a District. The epidiorite mass is also frequently invaded by granite which forms small islets or narrow elongated or even dyke-like intrusions. The latter possess a general E. W. trend, about 80°.

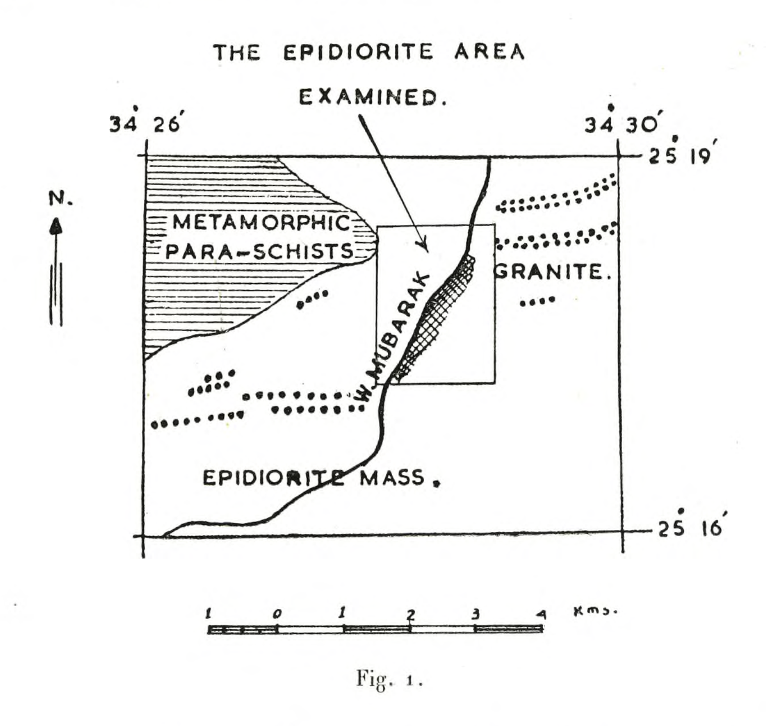


Fig. 1.

The metamorphic paraschists nearby consist essentially of granulite, hornblende schist and occasionally some micaceous hornblende schists or micaceous granulites.

III. The normal Epidiorite

The detailed study of the epidiorite mass revealed the complexity of this formation in the area examined. The mass consists dominantly of what is described here as normal epidiorite. This is a medium-grained equigranular rock. It is of dark green colour speckled in white due to

its constituents of green hornblende and milky feldspar. In slice, this rock consists essentially of pale bluish-green or green actinolitic hornblende and soda-lime plagioclase. The former is sometimes associated with chlorite and epidote while the feldspar is generally altered to sericite, kaolin and sometimes with epidote grains. Quartz and some biotite are occasionally present in the rock. The original ophitic texture of the epidiorite is sometimes preserved but generally it is partly obliterated. In this rock the hornblende usually exceeds the feldspar in amount. The petrographic character of this rock indicates its derivation from a basic igneous rock whose structure is partly obliterated but still it could be considered as epidiorite.

IV. The Complex Features of the Epidiorite Mass

This rock makes up the major part of the epidiorite mass examined. It is associated with numerous granite bodies as well as several complex features which are recorded along Wadi Mubarak in the area mapped in fig. 2. These features are described in detail in the following.

These features include the occurrence of :

1. Fresh Epidiorite relics; 2. Granitic injections; 3. The Xenolithic structure of epidiorite; 4. Schistose epidiorite; 5. Ortho and Paraschist masses.

1. *Fresh Epidiorite Relics.*

In the extreme northern part of the area examined (locality A, fig. 2), the normal epidiorite is associated with a small lenticular mass (about 20 metres in width) of brownish green epidioritic rock. It weathers into bouldery masses, measuring from 5-20 cms in diameter, which distinguishes it from the normal epidiorite. This rock is made up of actinolitic hornblende, soda-lime plagioclase and chlorite. These enclose lustrous spots up to one cm. in diameter. The spots consist of coarse hornblende plates enclosing fine plagioclase prisms with perfect ophitic texture. In the weathered surface of the rock the spots possess a dark green colour in comparison with the paler green groundmass.

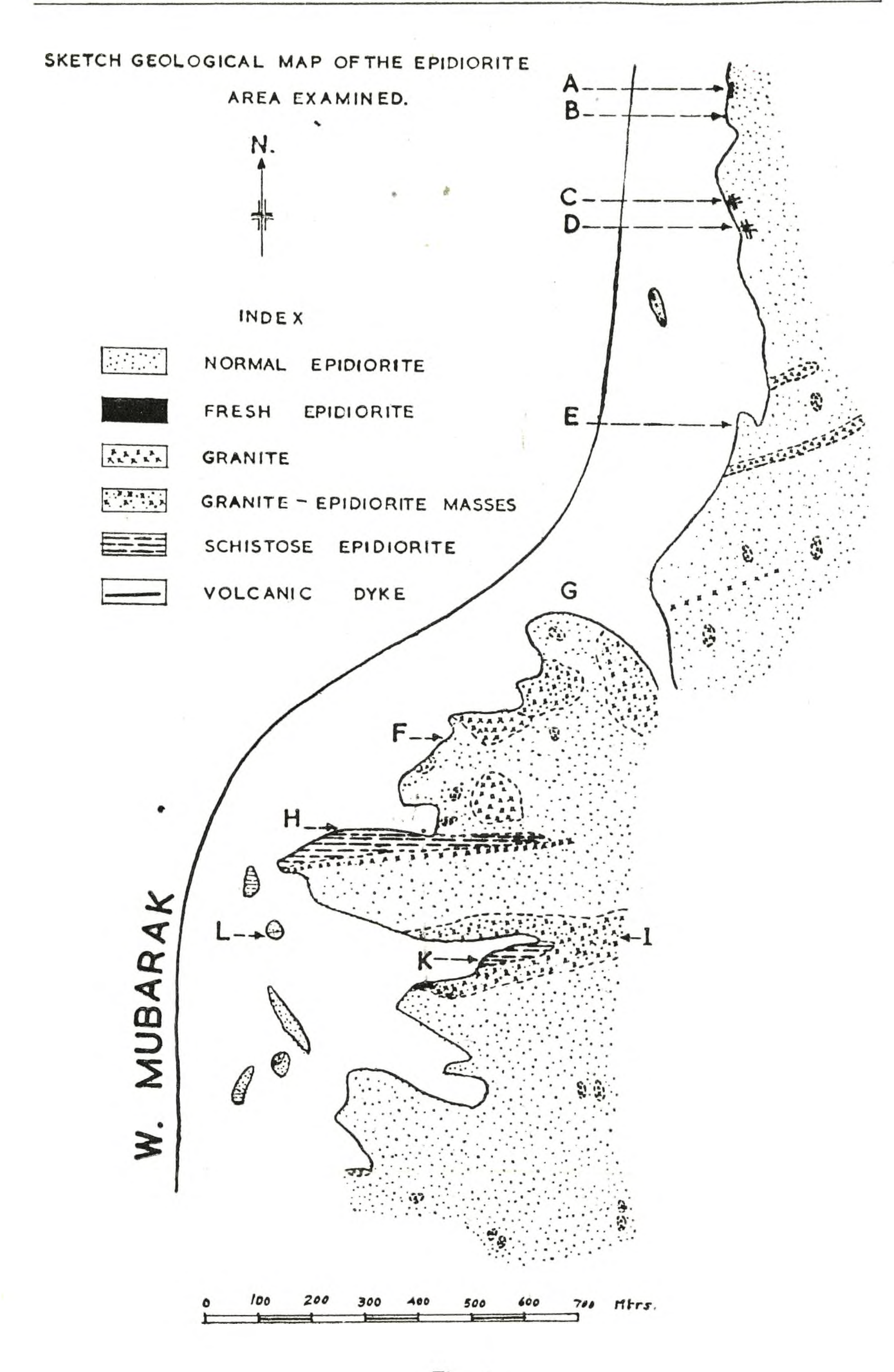


Fig. 2.

These spots are evenly distributed in the rock mass as shown in the diagrammed polished surface fig. 3. A similar rock is recorded in locality C (fig. 2). The hornblende of the spots is platy and with relics of diallage structure and the enclosed plagioclase is almost fresh. On the other hand, the hornblende of the groundmass is of finer grain and mixed with chlorite and partly altered plagioclase. The plagioclase in this rock is a soda-lime variety with Ab_{62} An_{38}.

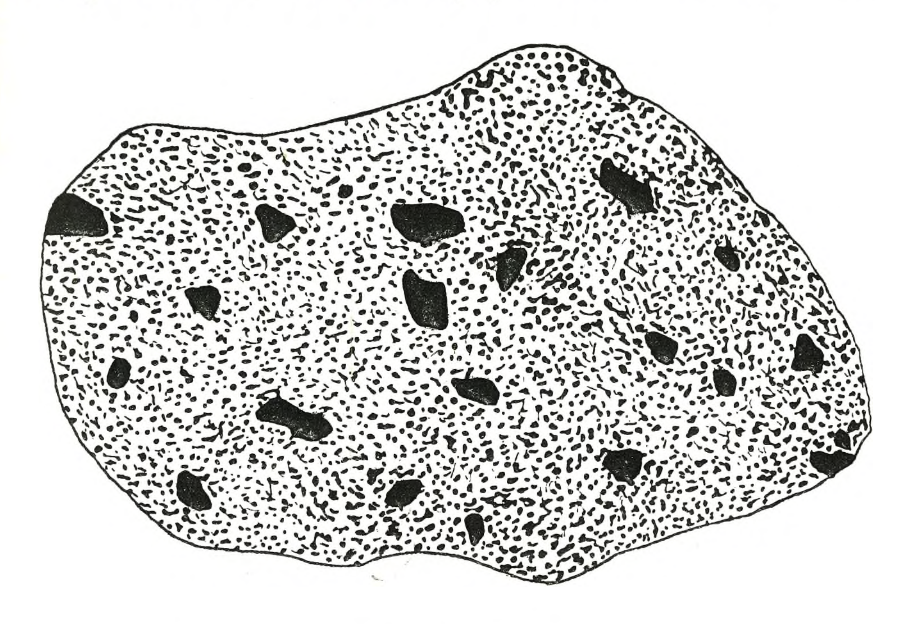


Fig. 3.—Polished surface of a fresh spotted epidiorite.

2. *Granite injections.*

The epidiorite mass is extensively injected by pink gneissose microcline granite. These either form narrow elongated masses as those mapped at the localities E and I (fig. 2) or rounded bodies as those widely distributed over the whole mass and those at the localities F and G. The contact of the granite and the epidiorite is generally gradational and is

marked by the interpenetration of the two rocks. The interpenetration of granite and epidiorite is observed in other localities (B and L fig. 2) where lit par lit injection and related phenomena are recorded. Likewise the association and intermixing of the granite and epidiorite is recorded on a large scale in localities G and I where the normal epidiorite encloses huge masses of these associations. The granite rock of these masses is a pink gneissose variety. It is a medium or fine-grained rock made of orthoclase, albitic plagioclase microcline and quartz. The microcline is fresh in comparison with the partly kaolinized orthoclase and plagioclase. The quartz shows strong undulose extinction. A few biotite flakes and magnetite grains are scattered in the rock. The rock is generally gneissose and fine-grained except for occasional porphyritic medium crystals of plagioclase.

3. *Xenolithic Structure of the Epidiorite rock.*

The epidiorite at the locality D (fig. 2) acquires a xenolithic structure. It is made of rather angular dark green xenoliths embedded in a dioritic matrix. The epidiorite xenoliths are of dark green colour with occasional coarse spots of hornblende same as those described previously in the fresh epidiorite. The xenoliths are rather angular as shown in fig. 4.

4. *Schistose Epidiorite.*

The normal epidiorite is usually a massive rock, but some schistose varieties are recorded in two localities H and K (fig. 2). These form two parallel belts striking 80° and dipping 60°-65° south. The width of these belts varies from 50-80 metres (fig. 2). They merge gradually into the normal epidiorite and granite-epidiorite country nearby. The schistose epidiorite is of dark green colour same as the normal epidiorite but is strongly schistose. In slice it is made of bluish-green hornblende, partly kaolinized and sericitized soda-lime plagioclase, some biotite and quartz. These form a fine-grained schistose matrix which enclose occasional medium-grained phenocrysts of plagioclase. These same as

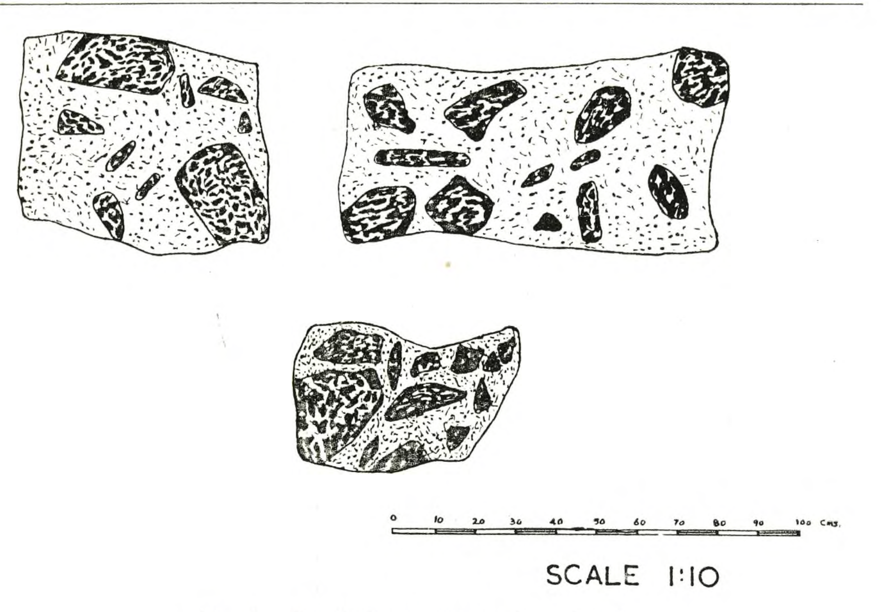


Fig. 4.—Xenolithic structure of the epidiorite.

the plagioclase of the groundmass are oriented. The hornblende is very pleochroic, with Z = pale yellow, Y = dark green, X = bluish-green and is associated with thin wisps of oriented biotite and magnetite grains.

5. *Ortho and Paraschist masses.*

Perhaps the most outstanding features of the examined epidiorite mass are those schistose rocks recorded in the localities B and L in fig. 2. In these localities, the normal epidiorite give way to hornblende schist which is associated with some highly injected paraschists. These two localities are described in detail below.

The normal epidiorite country rock at the locality B is associated with a huge lenticular mass of schistose rocks which is well exposed on the eastern side of Wadi Mubarak. It is of some 60 metres in width. The schistose rocks strike 65° and dip 85° southward. The schistose mass thins out and terminates into the epidiorite country on the eastern side. It is cut off by the Wadi on the western side and is apparently of lenticular form. A detailed cross section of this mass is sketched

in fig. 5. The cross section includes four main zones namely A, B, C and D.

A. The normal epidiorite on the northern side of the occurrence gives way to a semi-schistose epidiorite which encloses a small lenticle of micaceous granulite. This is envelopped in a narrow sheath of schistose epidiorite. The micaceous granulite is a rather slabby rock with grey colour. It consists of fine quartz and feldspar grains associated with coarser fragments of sodic plagioclase and quartz together with fine biotite flakes and epidote grains. The schistose epidiorite sheath surrounding that lenticle is a green schistose rock speckled in white. It consists of bluish-green hornblende prisms or plates associated with strongly altered plagioclase. The latter is oftenly accompanied by fine mosaic of almost fresh soda-lime plagioclase which may enclose few grains of quartz. The rock texture of the normal epidiorite is completely obliterated.

B. The epidiorite zone is followed southward by a 23-metres zone of banded pebbly schist which possesses pronounced sedimentary bedding structure (fig. 6). It weathers into rectangular slabs. This zone encloses three small lenticles of green hornblende schist. The banded pebbly schist is of greyish green colour. It consists of a matrix made of fine quartzo-feldspathic granules with abundant fine biotite and some hornblende. This matrix encloses numerous rounded or ovoidal pebbles of sodic plagioclase and of quartz. These are almost devoid of inclusions except for rare kaolin patches in the feldspar (fig. 10). The pebbly schist close to the lenticles contains a larger amount of hornblende than the main pebbly schist zone. The hornblende schist lenticles are of green colour and fine grain. They consist of green hornblende and kaolinized soda-lime plagioclase. The hornblende is associated with abundant magnetite grains and very few biotite flakes.

C. The pebbly schist zone is followed southward by a 14-metres zone of deformed hornblende schist which encloses small lenticles of epidioritic rock and deformed pebbly micaceous granulite. The hornblende schist zone is rather uniform. It is a dark green schistose rock speckled in white. It is a highly deformed rock which consists in slice, of spindle shaped augens of hornblende, feldspar and quartz embedded

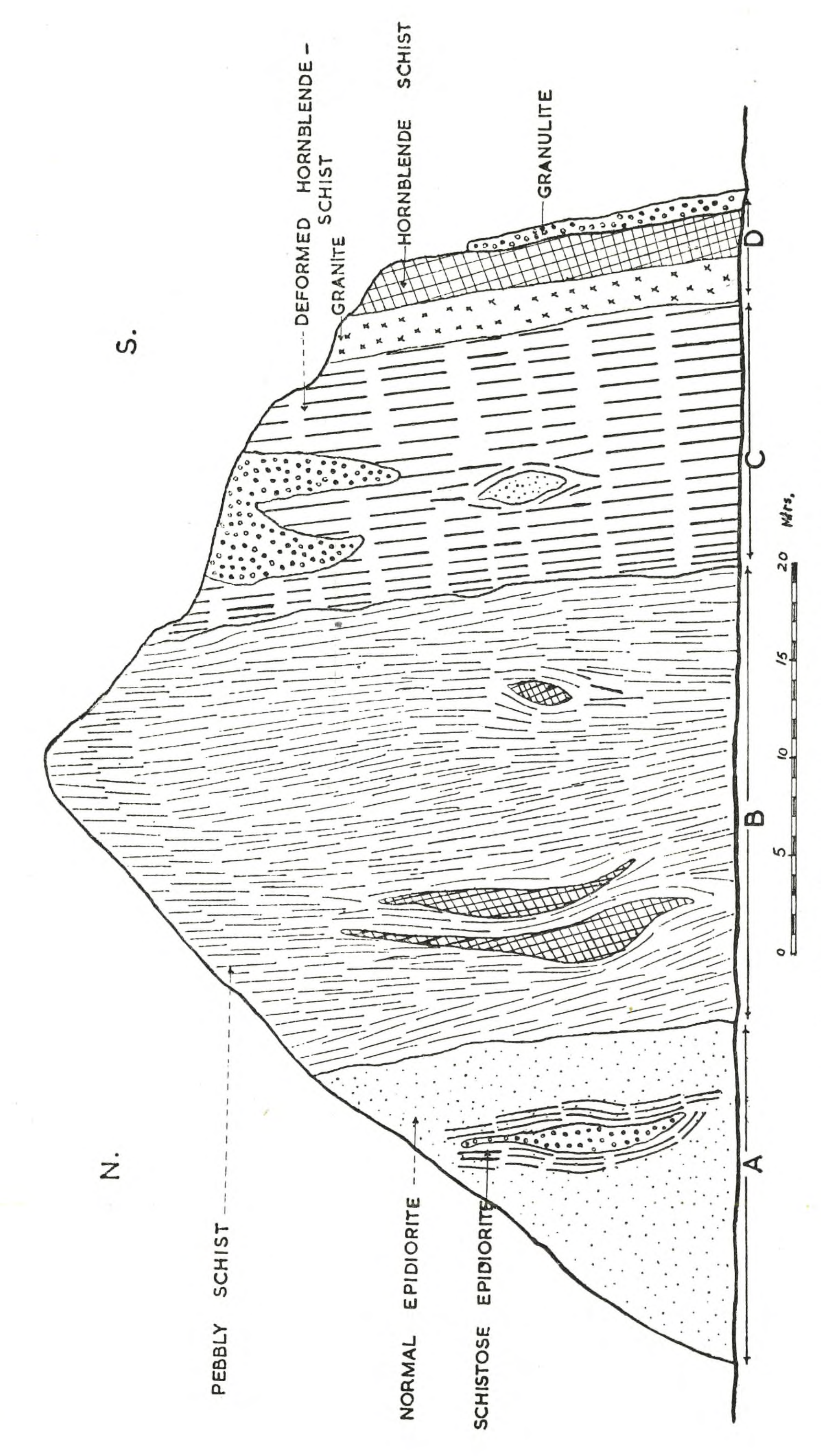


Fig. 5.—Cross section of the ortho and paraschist mass of loc. B, fig. 2.

in a fine quartzo-feldspathic matrix (fig. 9). The hornblende is a bluish-green pleochroic variety and is associated with some chlorite, magnetite, sphene and epidote. The feldspar is partly altered but is strongly deformed. The epidioritic rock lenticle enclosed in the deformed hornblende schist is of dark green colour and fine grain. The rock, though strongly transformed, still retains the outline of the original ophitic texture. It consists of green actinolitic hornblende and plagioclase. The hornblende forms aggregates of fine grains or



Fig. 6.—Bedding structure of the pebbly schist zone of the locality B.

fibres which still retain the outline of the parent ferromagnesian mineral. The feldspar forms fine laths embedded in the hornblende aggregates. These laths are either partly or completely replaced by fine quartzo-feldspathic mosaic which retain the outline of the original feldspar. The relics of the laths are partly altered to kaolin and heavily dusted with very fine inclusions (possibly rutile) (fig. 8); a feature which is oftenly found in the feldspar of the epidiorite rocks of the Nab'a District.

The deformed pebbly micaceous granulite lenticles recorded in the hornblende schist zone are relatively larger than the epidioritic lenticles. They are of pale yellow colour and consist, in slice, of fine matrix of quartzo-feldspathic granules and biotite flakes, enclosing ovoidal or rounded pebbles of quartz and feldspar same as those of the pebbly schist

described in zone (B). The matrix is drawn out into foliated schistose mass. Similarly the pebbles are deformed by undulose extinction and are almost oriented parallel to the schistosity of the matrix.

D. The extreme southern part of the occurrence consists of intercalated fine hornblende schist and granulite (fig. 6). The hornblende schist is the same as that of zone (B). The granulite is a much purer variety. It consists of fine quartz and feldspar granules associated with some biotite and little hornblende. The constituents of these rocks are strongly deformed and drawn out into parallel arrangement (fig. 11). In this occurrence, we have therefore an association of paraschists made of micaceous granulite, of pebbly schist, and of pebbly and normal granulites. These are associated with schistose epidiorite and related deformed hornblende schists.

The epidiorite country rock at the locality L (fig. 2) is associated with a highly injected schistose mass, which forms an island in the eastern side of Wadi Mubarak. The schistose rocks strike 65° and dip 55° southward. A detailed cross section of this feature is sketched in fig. 7, and described below. Three main zones are described in the mass namely A, B, and C.

A. The northern side of the island is made of normal massive epidiorite which encloses a lenticle of pink gneissose granite.

B. Southward the epidiorite is followed by a 10 metres zone of highly injected and contorted biotite hornblende schist with frequent lit par lit structure. The rock is very friable and is associated with a contaminated gneissose micaceous granite. This schistose rock encloses numerous lenticles or spindles which are usually contorted and occasionally drawn out into thin bands (fig. 7). The lenticles are mostly made of dark green compact hornblende schist. It is generally a fine-grained rock which consists, in slice, of bluish-green hornblende and soda-lime plagioclase with a gneissose structure. The hornblende is sometimes associated with some biotite and magnetite granules, and the feldspar is partly kaolinized and sericitized. Some of the lenticles are made of

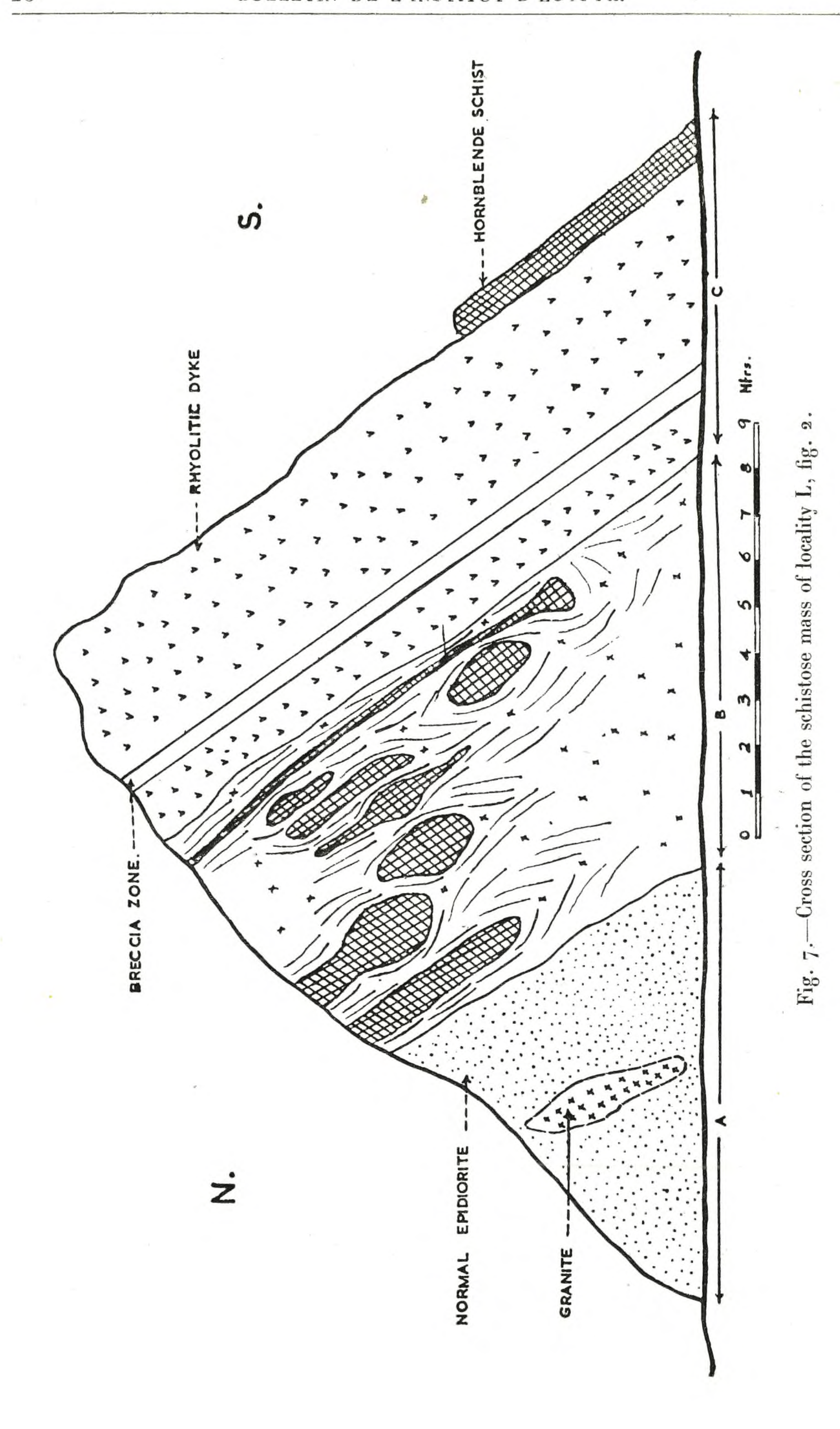


Fig. 7.—Cross section of the schistose mass of locality L, fig. 2.

medium-grained hornblende schists which, in slice, consist of pleochroic bluish-green hornblende and feldspar accompanied by some quartz and microcline. The hornblende in these rocks possesses the following pleochroism.

X = bluish-green, Y = dark-green, Z = pale-green

C. The injected schistose mass is followed by a highly deformed rhyolitic dyke. It is of some 6 metres in whidth and is broken by a breccia zone along which it is transformed into soft powder and fragments of the dyke rock. The dyke is followed by hornblende schist of almost the same nature as the lenticles enclosed in the injected schists of zone B.

Discussions and Conclusions

The described features of the epidiorite mass examined permit to consider the following aspect of the epidiorite formation :

1. The occurrence of the fresh epidiorite bodies among the normal epidiorite mass of the examined area is of important significance regarding the origin of this formation. These fresh relics are readily related to a parent gabbroic rock and their presence in this epidiorite mass confirms the genetic relations of this mass to the parent gabbroic rock as well.

2. The occurrence of the paraschist masses among the normal epidiorite examined, is perhaps the most interesting feature observed. The nature of these paraschists are readily determined by their outstanding bedding structure (fig. 6), as well as by their lithological character. They include granulite (which is sometimes impure or pebbly) and include also pebbly mica schists and hornblende schists. These schistose rocks are easily compared with the paraschists forming the country N. W. of the area examined. The paraschist masses are generally few in number but of moderate size measuring up to 30 metres in width. Generally they follow the regional strike and dip of the paraschist country nearby. These schistose rocks are oftenly confused with the schistose epidiorite or deformed hornblende schist produced from the

epidiorite. However, they can be distinguished by petrographic character as in the case described in locality B (p. 24).

3. The common association of the epidiorite mass examined with granite islets, or dyke-like intrusions, or stringers, indicates the frequent and wide-spread injection of the granite into the epidiorite mass. This has affected the epidiorite as well as its associated paraschists in which the granitic intrusions form lit par lit injections.

4. The epidiorite mass examined shows indications that it was subjected to some deformational stress. This is recorded in the development of schistose epidiorite belts (pages 22, 23) or deformed hornblende schists (page 24). The effect of this stress is also recorded on the pink gneissose granite masses as well as on the paraschists.

These described aspects indicate the complexity of the epidiorite formation whose study is one of the major problems of Egyptian Geology and which might lead to the establishment of fundamental events in our geological history.

ACKNOWLEDGMENT

We wish to express our grateful thanks to M. I. Attia, Director of the Geological Survey for permission to investigate this problem both in the field and office and for permission to publish it.



Fig. 9.—Photomicrograph of a deformed epidiorite showing the deformation of the hornblende and feldspar (X. 26).



Fig. 8.—Photomicrograph of an epidiorite from a lenticle in locality (B), showing the original ophitic texture of feldspar and hornblende (X. 26).



Fig. 11.—Photomicrograph of a banded micaceous granulite made of quartz, feldspar and mica (X. 26).

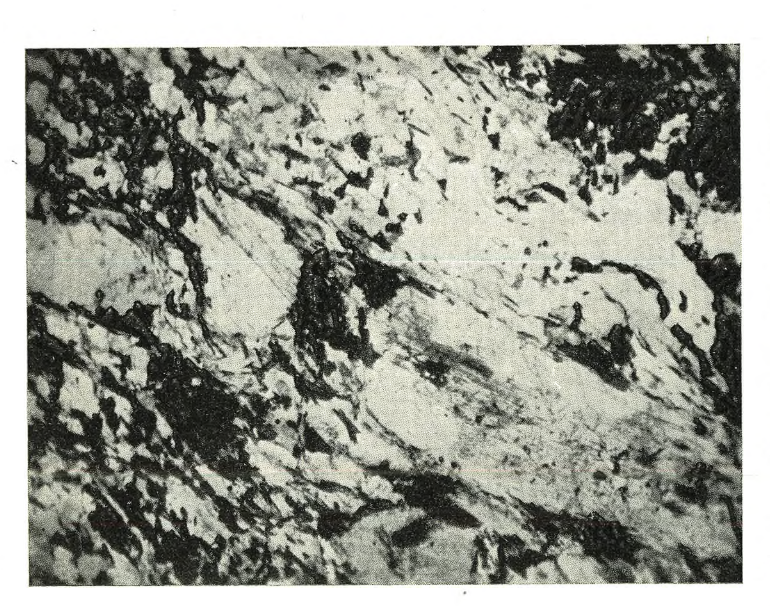


Fig. 10.—Photomicrograph of a pebbly schist made of feldspar pebbles in a fine matrix of quartzo-feldspathic grains and biotite (X. 26).

THERMAL HYSTERESIS OF ELECTRIC ROCK-CONSTANTS [1]

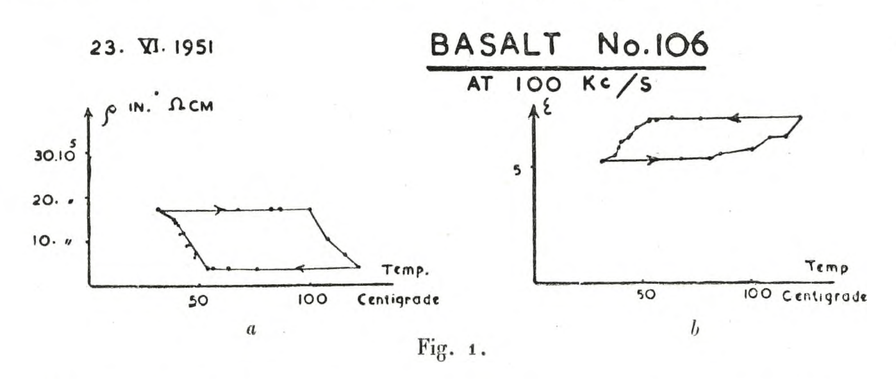
BY

H. LÖWY, Dr. Phil. (Göttingen)

Measuring the resistivity ρ and dielectric constant ε of desert rocks at different temperatures T, I observed a hysteresis phenomenon, illustrated in figures 1 and 2. The hysteresis curves show the following characteristics :

I. If the ρ T- and ε T- axes are chosen as in the figures, the variation along the resistivity curve is always clockwise, the variation along the dielectric curve always anti-clockwise.

II. Any of the two hysteresis curves contains two rectilinear parts parallel to the T—axis : The substance changes its electric constant only after having accumulated or lost a certain quantity of heat.



a *b*

Fig. 1.

Figure 1 *a* and *b* concerns basalt. The other chief representant of the igneous rocks, granite, also shows the phenomenon. It is with granite (disc n° 72) that the hysteresis has been first observed in December 1950. Concerning the chief mineral constituents of the igneous rocks,

[1] Communication présentée en séance du 3 mai 1954.

I observed the hysteresis with feldspars (orthoclase and plagioclase), with mica, hornblende, olivine, and hematite, *not* however with quartz, which has constant values of the resistivity and dielectric constant in the temperature interval from 30 to 140 degrees Celsius. The hysteresis of mica (fig. 2, *a* and *b*) is restricted to the resistivity, whilst the dielectric constant has been found independent of the temperature.

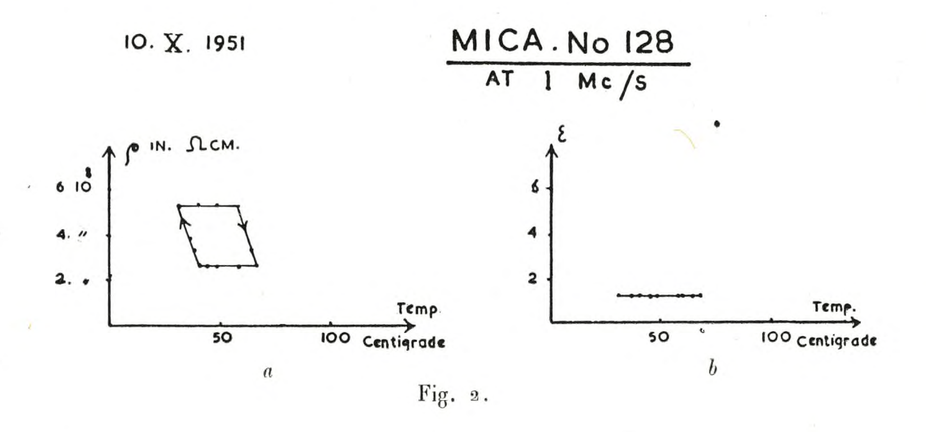


Fig. 2.

Concerning sedimentary rocks, I observed hysteresis only with shales. Certain very insulating Nubian sandstones as well as calcite, a mineral constituent of the sedimentary rocks, have constant values of ρ and ε in the indicated temperature interval.

The electric constants have been measured by means of the *Circuit Magnification Meter* of the *Marconi Instruments Ltd.* The condenser with the rock disc was enclosed in an *electric Thermostat* of *A. Gallenkamp Ltd.*, London. The temperature slowly increased from 30 to 140 centigrades and slowly returned to its initial value. The whole temperature cycle lasted about one hour.

The temperature, indicated in figures 1 and 2, has been measured in the air near the condenser, with the thermometer sometimes even intact with one of the condenser plates. The question is, whether the temperature, measured at the condenser plate, can be considered as the temperature of the rock sample.

For simplification, I suppose that the rock disc has infinite thickness and that the periodic variation of temperature is applied to one condenser plate only. Thus our question is reduced to the well-known *problem of underground temperature*, that is, the problem to determine, for a given periodic variation of temperature at the Earth's surface, the temperature in the interior of the Earth, as function of time t and depth x. In the following, I apply this theory in the form, presented in § 14, vol. 6 of *A. Sommerfeld's* « Vorlesungen über theoretische Physik » (Wiesbaden 1947).

The temperature oscillation at the condenser plate excites a temperature wave propagating into the interior of the rock disc :

$$(1) \qquad T(x,t) = C_o + 2 \sum_{n=1}^{\infty} |C_n| \, e^{-q_n x} \cos\left(2\pi n \frac{t}{\tau} + \gamma_n - q_n . x\right)$$

The amplitude $|C_n|$ of the nth partial wave is damped and retarded in phase relative to the exciting oscillation. The damping is determined by the factor $e^{-q_n x}$, the retardation of phase γ_n is $q_n . x$, where

$$(2) \qquad q_n = \sqrt{\frac{|n|\pi}{\varkappa \tau}}$$

$\varkappa$ is the thermometric conductivity, τ the period of temperature variation, that is, the time of one hysteresis cycle. In our experiments, it is about one hour : $\tau = 3.6 . 10^3$ sec.

For Basalyt $\varkappa \sim 10^{-2}$ cm^2 sec^{-1}. Thus we obtain for the fundamental wave (n = 1), acc. to (2), q = 0.29. The thickness of the rock disc being about one millimetre, we put $x = 10^{-1}$ cm., and obtain:

$$q_1 \, x = 0.029 \sim \frac{\pi}{100}$$

that is, a *small retardation in phase*, and

$$e^{-q_1 x} \sim 0.971,$$

that is, *little damping*.

THEORETICAL CONSIDERATIONS
CONCERNING
A HYDROLOGIC DUNE PHENOMENON [1]

BY

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In his *Geology of Egypt,* W. F. Hume (1925) pointed to the practical importance of a hydrologic phenomenon, which according to A. Daubrée (1887) has been observed in the coastal dunes of France and Holland and which, in Egypt, has been utilized for water supply in sandy parts of the desert : the water table was found to follow the surface contours of the dunes, but with the amplitude of its undulations less pronounced than those of the dunes themselves (Hume, *l. c.*, vol. I, p.55).

The following is an attempt to explain the phenomenon by combining *Hagen-Poiseuille's law* with the evaporation theory of J. Stefan (1874).

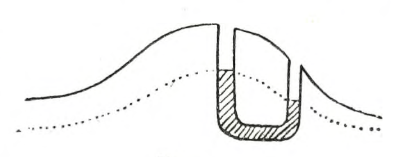


Fig. 1.

For simplification, I consider, instead of the whole dune, the system of communicating tubes which correspond to two points, situated at different altitudes of the dune surface. In figure 1, I have reproduced from Hume's work (*l. c.* Plate XVIII between pages 56 and 57) the diagrammatic section of water bearing dune strata. I have added the corresponding system of communicating tubes. The vertical parts of this tube system are of different lengths. The movement of the water levels in this tube system is caused partly by evaporation, partly by Hagen-Poiseuille flow. The flow is caused by the water load

$$g\ d\ r^2\ \pi.\quad (A + h - H)$$

where g signifies the acceleration of gravity, d the density of water

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[1] Communication présentée en séance du 3 mai 1954.

r the tube radius, A the difference of altitudes between the two points of the dune surface, and H and h the depths (relative to the dune surface) of the levels in the longer and shorter vertical parts of the tube system, respectively. On the other side, the flow is resisted along a (curved) water cylinder of length $l = L - (h + H)$, in which L signifies the total length of the tube system.

The volume of water, flowing in unit time through the tubes is, according to *Hagen-Poiseuille's law*

(1) $$W = r^4 \pi P / 8\mu$$

μ is the coefficient of viscosity, P the pressure gradient which, in our case is

(2) $$P = g\ d\ (A + h - H)\ /\ [L - (h + H)]$$

The flow produces in unit time a level change $\pm W/r^2\pi$ in the vertical parts of the tube system.

The changes of level in unit time dH/dt and dh/dt in the longer and shorter tube respectively are obtained by adding algebraically the flow velocities $\pm W/r^2\pi$ and the evaporation velocities C/H and C/h respectively. C is *Stefan's evaporation constant* which plays a fundamental rôle in the theory of ground-water accumulation (Löwy 1945 and 1947).

By addition of velocities we obtain the following two differential equations for the two unknown functions h and H of time t :

(3) $$\begin{cases} dh/dt = C/h - W/r^2\pi \\ dH/dt = C/H + W/r^2\pi \end{cases}$$

Putting

(4) $$B = r^2 g\ d / 8\mu [L - (h + H)]$$

we can write (3) in the form

(5) $$\begin{cases} dh/dt = C/h - B(A + h - H) \\ dH/dt = C/H + B(A + h - H) \end{cases}$$

Substracting the first equation (5) from the second we obtain

(6) $$d(H-h)/dt = 2BA - (2B + C/Hh)\ (H-h)$$

The quantity B depends on the unknown functions h and H. As long as there is water in the tubes, we have

(7) $$L > h + H.$$

B is therefore positive. The same is true for A and C/Hh.

Thus we find, according to (6) :

(8) $$dH/dt < dh/dt \qquad \text{for } H - h \geq A.$$

If therefore, at any time, the water table was rising in direction from the dune top to the dune valley ($H - h > A$), it will turn in a horizontal position and, after having reached the horizontal position ($H - h = A$), it will continue to turn in the sense, indicated by Daubrée, that is, in positions more or less parallel to the dune surface.

The hydrodynamical members in equations (5) are equivalent to *Darcy's law*, according to which the unit flow $B(A + h - H)$ is equal to the product of the permeability $r^2 gd/8\mu$ and the hydraulic gradient $(A + h - H)/[L - (h + H)]$.

As example we consider the practically interesting case that ground water accumulates in shallow depth beneath the surface of the dune valley. This is the case in North Egypt. Hume (1925, p. 55) mentions that « the inhabitants of the sea coast living east of Baltim are entirely dependent upon pools formed at the foot of the dune.» In this case, h has even a negative value. In our example we put $h = +20$ cm. At 33 degree Celsius, *Stefan's constant* is $C = 10^{-5}$ cm²/sec. *the evaporation velocity* is, therefore $C/h = 5.10^{-7}$.

According to Hume (1925), the longitudinal dunes in the *Western Desert of Egypt* are several kilometres broad and attain altitudes of 30 m. (*l. c.* p. 35). If the impermeable layer on which the dunes rest, is less that 20 m. beneath the surface of the dune valley, the value of $H + h$ in the equivalent tube system is smaller than $(30 + 20) + 20 = 70$ m. The quantity L, on the other hand, is equal to half the dune breath, if the openings of the vertical tubes are placed at the dune top and the dune valley, respectively. We put, in our example, $L - (H + h) = 2.10^5$ cm., and the altitude of the dune $A = 10^3$ cm. In the case of Daubrée's phenomenon h is nearly equal to H, and the hydraulic gradient becomes $10^3/2.10^5 = 5.10^{-3}$.

Marine offshore deposits of very fine sand which constitute these coastal dunes have permeabilities as low as 10^{-4} cm/sec. (Terzaghi and Peck 1948, table 14, p. 330). The velocity of flow is, therefore, $10^{-4} . 5.10^{-3} = 5.10^{-7}$ cm/sec, that is of the same order as the evaporation velocity.

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THE SKELETAL STRUCTURE OF *PARIOXYS FERRICOLUS*, COPE [1]

BY

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Introduction

The rare rhachitomous amphibian *Parioxys ferricolus* occurs in the Belle Plains Formation of the lower Permian Redbeds Wichita Group in Texas. This obscure species was first described by E. D. Cope (1878) from two small skulls the identity of which was recently ascertained by the writer (Moustafa, 1952).

In January, 1948, the writer started an investigation of the structure and affinities of *Parioxys* based on the material housed in the Museum of Comparative Zoology at Harvard.

MATERIALS AND METHODS

The study of the structure and affinities of *Parioxys* was made on a number of partial skeletons which were collected in 1934 and 1935 by the Museum of Comparative Zoology at Harvard College, U. S. A. (referred to throughout this work as M. C. Z.) from the Wichita Group of the lower Permian Redbeds of Texas. The identification of these specimens as belonging to *Parioxys ferricolus* was confirmed by the writer through comparing the M. C. Z. material with the original type specimen of the species in the American Museum of Natural History, New York, U. S. A. (Moustafa, 1950, p. 13; 1952, p. 298). The specimens investigated were made available through the courtesy of

[1] Communication présentée en séance du 7 décembre 1953.

Professor Alfred S. Romer, Director of the Museum of Comparative Zoology at Harvard, under whose supervision this investigation was conducted.

The different specimens examined for this work are listed below, with special references to their locality, horizon, collector, and specific numbers given to them in the M. C. Z. collection.

M. C. Z. n° 1162 *Parioxys ferricolus*.

This was collected by Mr. L. I. Price in the summer of 1934 at a locality north of the little Wichita River in J. Gibbs Survey, Abstract 566, Baylor Co., Texas. This locality is southwest of Dundee, Archer Co., a short distance west of the county line. The horizon is the Belle Plains Formation of the Wichita Group. Included under this number was a large mass of fossiliferous sediments, dark red in color, occurring in one pocket, which, on preparation, yielded a number of good specimens. These include :

1. A fairly good skull of a large individual with the two rami of the lower jaw in an articulated condition (1162 A). The measurements of this skull (Table 1) show that it probably belonged to an adult individual. The description of the skull of *Parioxys* is based largely on this specimen (plates I-II).

2. The anterior part of the skull roof, palate and mandibles of two individuals. One is of the same size as 1162 A, and is presumably of an adult; the other is slightly smaller, probably belonging to a young adult. The specimens are numbered 1162 A' and 1162 B respectively.

3. The anterior portion of the skull roof and lower jaws of a small individual, presumably very young (1162 C).

4. The left mandible of a presumably young adult, missing the symphysial and articular portions. Most of the sutures were readily determined on this specimen (1162 D) as a result of the sliding of the bones past each other along them (plate II, figs. 1-4).

5. The anterior portion of a left mandible (1162 E), slightly larger than 1162 D.

6. The right mandible of a presumably young adult slightly smaller than 1162 D. This specimen (1162 F) is broken at the posterior part of the angular and near the symphysis.

7. The symphysial portion of the left and right mandibles of a presumably young individual (1162 G).

8. The articular, quadrate, a part of the squamosal, quadratojugal, and the ascending ramus of the pterygoid of the right side, probably belonging to the adult skull 1162 A' (plate III, figs. 5 A, B).

9. The greater part of the palatine and ectopterygoid, and the anterior part of the pterygoid of the right (1162 H, plate III, fig. 4), and left sides. The latter (1162 D') was associated with mandible n° 1162 D (plate III, fig. 2).

10. A parasphenoid lacking the cultriform process (plate III, fig. 6).

11. A portion of the vertebral column associated with the large skull n° 1162 A, consisting of a number of presacral vertebrae (plate IV, fig. 1) with their neural arches in position, and the sacrum attached to a portion of the iliac blade (plate IV, fig. 2). Moreover, various portions of the presacral regions of the vertebral columns of a number of individuals were found in the same kind of matrix, with some ribs in association. A number of caudal vertebrae were found partly enclosed in matrix, and partly free.

12. A slightly distorted left sacral rib (plate VIII, fig. 1 C).

13. The proximal parts of two cleithra, one of the left side (plate V, fig. 1), and the other of the right, together with a fragmentary cleithral shaft.

14. The distal part of a left clavicle (plate V, fig. 5), and a fragmentary clavicular shaft.

15. Three incomplete scapulocoracoid plates of the right side, two of which are figured in plate VI. Text figure 7 is a composite of all three specimens.

16. Two complete scapular blades of presumably an adult, together with two fragmentary blades of almost the same size. One of the complete specimens is figured in plate V (fig. 4).

17. Six humeri. Two are complete, right and left, belonging with skull n° 1162 A to the same individual (plate V, fig. 3; plate VII,

fig. 1, respectively). In addition, there are the distal ends of three humeri of equal size; two of these are of the right side, the third being of the left. The sixth specimen is a small complete left humerus, probably of a young individual (plate VII, fig. 2).

18. Five radii. Two are represented by their proximal ends and a portion of the shaft; the other three are distal ends. Of the former, one was associated with skull n° 1162 A (plate V, fig. 2), while of the latter a large specimen is figured in plate IX, fig. 8.

19. Four pelvic girdles. A badly distorted left one was found inserted between the jaws of skull n° 1162 A. The other three are all of the right side and are slightly smaller than the left. Of these, an almost complete one (plate VIII, fig. 1) provided the restoration given in Text figure 8.

20. Four femora. A complete right (plate VIII, fig. 2) and the distal part of a left were found associated with skull n° 1162 A; the third is a left, represented by its distal end. The fourth femur is smaller, presumably of a young individual (plate VIII, fig. 3).

21. Proximal parts of four tibiae. Two are probably the right and left of the same young adult individual. The third is of the right side and is larger (plate IX, fig. 4), while the fourth is a much smaller left.

22. Distal part of the fibula (plate IX, fig. 7), associated with skull n° 1162 A.

23. Foot material consisting of an articulated incomplete pes and a number of disarticulated phalanges and metatarsals (plate IX, fig. 3).

In addition to the M. C. Z. material listed above, the writer also studied the specimens on which the species was based in 1878 (Cope, 1878; Moustafa, 1952). These two skulls were made available through the courtesy of Professor George G. Simpson of the American Museum of Natural History, New York (referred to as A. M. N. H.).

A. M. N. H. n° 4309 *Parioxys ferricolus*

This is the holotype of *Parioxys ferricolus,* Cope (Moustafa, 1952, p. 298, plates I-III, fig. 1). The measurements of this skull (table 1) show clearly that it belonged to a young individual. The specimen was

collected by Ball and Isaac on the 7th of February, 1878, at a locality near Mount Barry, Belle Plains Formation, ten miles of Wichita Falls, Texas, U. S. A.

A. M. N. H. n° 2445 *Parioxys ferricolus*

This specimen comes from the same locality and horizon as the type of *Parioxys.* It consists of a small skull with the lower jaw articulated (Moustafa, *op. cit.,* plates I-III, fig. 2). Its measurements given on table 1 indicate that it belonged to a young individual.

The description of *Parioxys ferricolus* given below is, as far as possible, that of the species as a whole, rather than that of individual specimens. Although a comparative study and analysis of the structure of the species is reserved for a later publication, references to the structure of other amphibian types are made whenever it is found to be of value to the understanding of the structure of *Parioxys.*

AXIAL SKELETON

I. Skull.

(Text figs. 1-2, Plates I-III)

A. *General Features of the Skull.*

The general shape of the skull of *Parioxys* and the relative position of the orbits and otic notches make it possible to include this form in Watson's «group 4» of rhachitomous skull types (Watson, 1919, p. 50), which includes «animals with a flat-topped head, laterally placed orbits and otic notches». It may be added here, however, that certain features that characterize the «central» type of skulls (group 1 of Watson) are also present in *Parioxys.* These include the possession of a somewhat wide muzzle and the posterior position of the orbits. The presence of such combination of features is probably due to the partial retention of certain primitive features in a form which has progressed toward a terrestrial mode of life. The skull of *Parioxys* is relatively high.

The ratio of its maximum width in the region of the quadratojugals to its height (taken between parallel lines projecting from the tips of the orbits and the transverse portion of the pterygoids) is 0.445. It is thus higher than that of *Eryops*, in which the ratio is only 0.330 (Sawin, 1941, p. 413), and is of almost the same height as that of *Trematops* (personal observation).

B. *Skull Surface Topography*.

(Plates I-II)

When viewed from above, the skull of *Parioxys ferricolus* is triangular with a slightly broad rounded muzzle. When viewed from in front, the margin of the skull in the muzzle region exhibits an upward arch which joins the lateral borders at the level of the anterior corner of the external nares. The skull is moderately depressed in the antorbital region, while the skull table is considerably higher. As a result, the whole skull roof slopes anteriorly, more so in the young individuals than in the adults. The table is markedly set off from the laterally sloping ckeeks. The bones forming the ventral border of the orbital openings are also set off from those forming the muzzle by a deep concavity at the anteroventral corner of either orbit.

The quadrates are far back of the level of the occiput. The otic notches are well rounded; they are larger than those of *Eryops* (Sawin, 1941), and slightly smaller than those of such forms as *Dissorophus* (M. C. Z. material, personal observation), *Cacops* (Williston, 1910; Case, 1911, pl. 17, fig. 3), or *Trematops* (Olson, 1941). Anterior to the otic notches the skull table and cheeks are firmly fused.

The external nares, facing dorsolaterally, are placed far forward, quite close to the lateral margins of the skull in a typical temnospondylous fashion (Romer, 1947, p. 19, etc.). Each narial opening is an equilateral spherical triangle. Between the two nares and at the level of their anterior corners there is a small round median internasal pit. The posterior position of the orbits is comparable to that of *Chelydosaurus* (Fritsch, 1901, pl. 56), *Sclerocephalus* (Branca, 1866), and

Onchiodon (Credner, 1893). Compared with those of *Eryops* (Sawin, *op. cit.*), they occupy a slightly more anterior position, while they are situated posteriorly relative to those of *Cacops* and *Dissorophus* (Williston, 1910 and 1910 *a*, respectively). They look laterally and slightly dorsally in the young adult and adult individuals; in the immature individuals, however, they look directly dorsally. The parietal foramen is quite large and oval. It is placed slightly in front of the mid-length of the suture between the two parietal bones, anterior to a line drawn across the posterior borders of the orbits.

The distance between the narial and orbital openings is short compared to that between the latter and the posterior margin of the skull table in the immature *Parioxys*. In the young individual the two distances are about equal, while in the young adult and adult the distance in front is approximately twice that behind the orbits. This indicates that *Parioxys* had one zone of « intensive growth » from the immature to the mature stages, and that this took place in the region between the orbits and nares, a condition quite similar to that described for *Cyclotosaurus* (Bystrow, 1935) and *Eryops* (Sawin, *op. cit.*).

The dermal bones of the skull roof are generally thin. They are ornamented by pits and anastomosing ridges that radiate from their centers of ossification, as described for various amphibians by Bystrow (*op. cit.*), and best displayed in the case of *Parioxys* by the premaxillae, postparietals, and nasals, particularly the last. There are no lateral line grooves, confirming the conclusion that *Parioxys ferricolus* was a terrestrial amphibian.

C. *Dermal Skull Roof*.

(Text fig. 1)

In treating the separate elements of the skull roof, these are grouped, following Romer (1933, p. 81; 1949, p. 220), with but a slight modification.

The premaxilla forms the anterior margin of the muzzle, both the anterolateral and anteromedial borders of the external narial opening, and the anterolateral rim of the internasal pit. Posteriorly, and medial

to the naris, it meets the nasal, while lateral to that opening and close to its anterior corner, it meets the maxilla. The center of growth of the premaxilla lies in its mid-length, opposite the middle of its suture with the nasal.

The maxilla is a very long narrow bone which forms the greater part

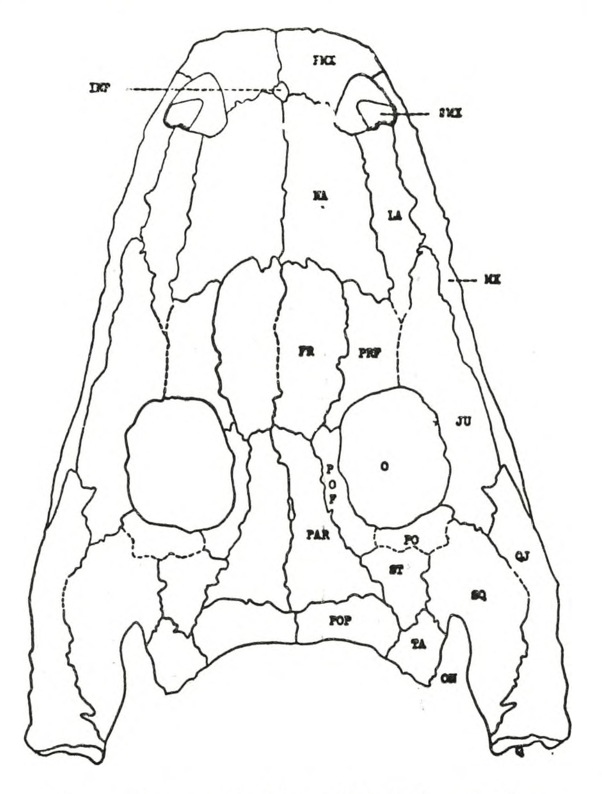


Fig. 1. *Parioxys ferricolus*. Skull in Dorsal View.

of the lateral margin of the skull. It is in contact with the premaxilla lacrimal, jugal, and quadratojugal. The breadh of the bone is not constant; along the lacrimal it is broader than along the jugal. It forms the base for the attachment of tbe posterolateral portion of the septomaxilla. The latter is a thin unsculptured bone which occupies a posterolateral position in the external narial opening, lying, as in all advanced rhachitomes, below the general level of the dermal bones.

The nasal is the largest bone in area on the skull roof. It forms the posterolateral margin of the internasal pit as well as the posteromedial border of the external naris. It is in contact with the premaxilla, lacrimal, frontal and prefrontal. The nasal is twice as broad posteriorly as anteriorly, and its center of ossification lies exactly at the point of intersection of two diagonal lines connecting its opposite corners.

The frontal is a roughly triangular bone, slightly smaller than the nasal. It is in contact anteriorly with the nasal, laterally with the prefrontal, posterolaterally with the postfrontal, and posteriorly with the parietal. The center of growth of the bone lies in the middle of its anterior half.

The parietal is a triangular bone occupying the central portion of the skull table. It is in contact with the frontal, postfrontal, supratemporal, and postparietal. It does not come in contact with the tabular, a temnospondylous feature. The common suture between the parietals of both sides is interrupted anterior to its mid-length by the oval parietal foramen.

On the skull table, the exposure of the postparietal is narrower anteroposteriorly than mediolaterally. The bone is in contact with the parietal, supratemporal, and tabular. The postparietals of both sides participate in the formation of the greater part of the concave posterior border of the skull table. The center of ossification of the postparietal is situated in its center.

The supratemporal is a medium sized triangular bone with irregular borders. It is surrounded by six bones : the postparietal, parietal, postfrontal, postorbital, squamosal, and tabular. It is slightly thicker than those previously described.

The tabular is a roughly diamond-shaped bone, the center of growth of which lies exactly in its center. Its posteromedial border takes part in the formation of the posterior margin of the skull table, while its lateral border forms the dorsal edge of the otic notch. It meets the supratemporal, parietal and squamosal. The surface of the bone is slightly tilted posteriorly.

The prefrontal is the second largest bone of the circumorbital series, being exceded only by the jugal. It extends slightly less than half the

distance between the orbit and naris. It is in contact with the frontal, jugal, nasal, and lacrimal. Anteromedially, it wedges between the nasal and frontal. The prefrontal forms the anterodorsal margin of the orbit, and is bounded posteriorly by the postfrontal.

The postfrontal is much narrower than the prefrontal. It forms the greater part of the dorsal rim of the orbit. It is in contact with the frontal, prefrontal and supratemporal, and seems to be in touch with the postorbital, while medially it has a long suture with the parietal.

The postorbital is the smallest bone of the skull roof. It forms the posterior border of the orbit, and is about equally shared between the skull table and cheek. It contacts the jugal, postfrontal, supratemporal, and squamosal.

The jugal is the major constituent of the cheek region. It forms the entire ventral margin of the orbit. It is in contact with the maxilla, quadratojugal, squamosal, postorbital, lacrimal, and prefrontal. The jugal is very fragile with but very little sculpture.

The lacrimal is a long, roughly trapezoidal bone which enters broadly into the formation of the posterior border of the external narial opening. It is in contact with the maxilla, nasal, prefrontal, and jugal; thus it does not take part in the formation of the orbital border.

The quadratojugal is the second longest bone of the skull, forming the posterior third of its lateral margin. It is in contact with the quadrate (which it overlaps), jugal, maxilla, and squamosal.

The squamosal is a dorsoventrally broad bone which forms the anterodorsal, anterior, and ventral borders of the otic notch. It is coarsely sculptured, with well rounded margins. The posteromedial portion of the bone turns inward at approximately right angles to form a sculptureless lamella which joins the pterygoid.

The architecture of the skull surface of *Parioxys* is strikingly similar to that of *Chelydosaurus* (Fritsch, 1901, vol. 2, pp. 18-27, pl. 56-58; Steen, 1938, pp. 248-249, fig. 34), and it is not impossible that this genus is one of the close relatives of *Parioxys*. However, in the absence of additional data concerning the remainder of the skeleton of *Chelydosaurus*, especially its palate, such a similarity cannot be heavily counted upon as being an evidence of a real relationship between the two genera.

D. *Palatal Structure.*

(Text fig. 2; Plates I, and III, figs. 2-4)

The margins of the skull of *Parioxys*, as seen from the palatal side, are formed by the premaxillae, maxillae, quadratojugals, and quadrates.

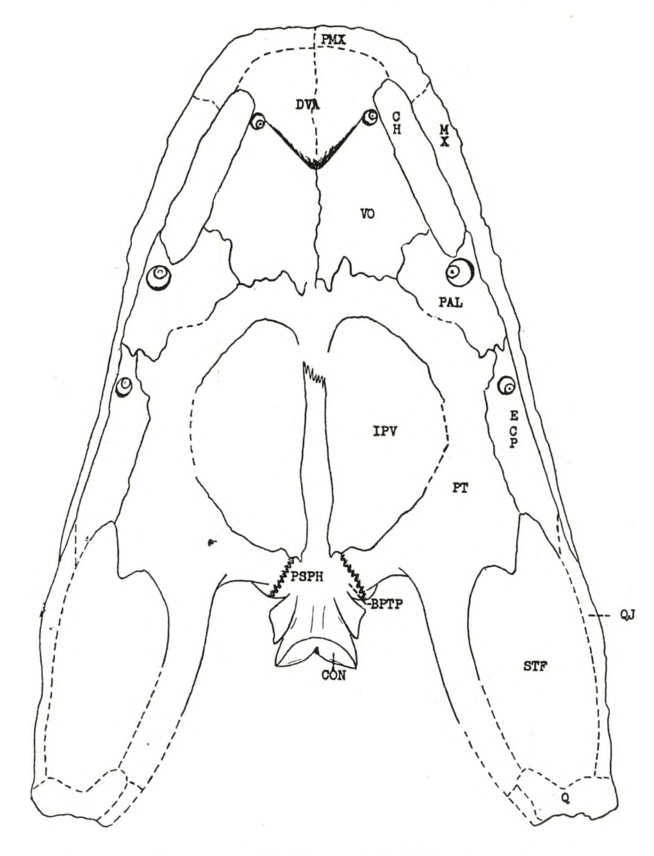


Fig. 2. *Parioxys ferricolus*. Skull in Palatal View.

In addition to the marginal elements, the palatal surface of the skull is formed by four pairs of bones of dermal origin, including the vomers [1]

[1] Parrington and Westoll (1940) have presented strong evidence to show that the bone frequently termed « prevomer » in amphibians and reptiles is homologous with the vomer of mammals.

palatines, ectopterygoids and pterygoids. These form a more-or-less horizontal surface, interrupted anteriorly by the internal narial openings, toward the mid-line by the moderately developed interpterygoid vacuities, and posteriorly by the subtemporal fossae (the adductor fenestrae of some authors, e. g. Sawin, 1941). A large number of small denticles (unfortunately, and unavoidably, destroyed during preparation) were present on all four pairs of bones.

The choanae are widely separated and laterally placed, with their anterior tips underlying the posterior portion of the external nares. Their posterior and lateral position is a typical temnospondylous character. They are extremely elongate in an anteroposterior direction, a condition which is not paralleled in any other known amphibian with a skull of normal labyrinthodont skull proportions and external nares. The only approach to such a condition is found in *Cacops* (Williston, 1910; Case, 1911, pl. 17, fig. 2), in which the choanal elongation is much less than in *Parioxys*. It is interesting to note that the internal nares of *Parioxys* parallel in their development those of the long-snouted contemporary rhachitome *Chenoprosopus* (Williston, 1918, pp. 93-95, fig. 7). The relationship between the lengths of the internal and external nares of *Parioxys* is the reverse of that existing between them in *Trematops* (Williston, 1909; Case, 1911, pl. 14, fig. 3; Olson, 1941, fig. 8A), in which, although the internal nares are elongate, they are still smaller than the external, and their elongation is correlated with that of the latter. The medial border of each internal naris is jointly formed by the vomer and palatine, while its lateral margin is formed by the maxilla.

The interpterygoid vacuities are of a moderate size intermediate between those of *Eryops* (Sawin, 1941, pl. 2) and *Cacops* (Williston, 1910; Case, 1911, pl. 17, fig. 2). The vacuities are broad from side-to-side, especially at the middle of the palatal ramus of the pterygoid. Anteroposteriorly they are short. Only *Acanthostoma* (Steen, 1937) shows such shortness of interpterygoid vacuities. The vacuities of *Parioxys* are separated along the middle line by the cultriform process of the parasphenoid; posteriorly, each vacuity is bordered by the basipterygoid process of the braincase.

The subtemporal fossae are of almost the same size as the interpterygoid vacuities, occupying a posterolateral position on the underside of the skull. Their medial borders are provided by the quadrate rami of the pterygoids, while their lateral boundaries seem to be furnished by the quadratojugals. Posteriorly they are bordered by the quadrates, while the palatal rami of the pterygoids participate with the ectopterygoids in the formation of their anterior margins.

The marginal teeth in *Parioxys* are sharp, conical and long; they alternate with pits in a typical labyrinthodont fashion. The alternation, however, is not regular. Counting the teeth and pits together, each premaxilla carries six, about four of which, and possibly five, are functional at any given time. The sixth premaxillary and first and second maxillary teeth are the largest, the rest being smaller and of essentially uniform size throughout the tooth row. The maxilla has at least thirty teeth and pits. Of these at least twenty four are functional on either side.

The vomers are thin trapezoid bones which are bound by the pterygoids posteriorly and the premaxillae anteriorly. The anterolateral portion of the dorsal surface of each vomer is concave from side-to-side medial to the border of the internal naris, apparently for the accomodation of the anterior portion of the cartilaginous nasal capsule. On the ventral surface there is a strong, pointed conical fang, accompanied by a shallow pit, situated a short distance behind the anterior end of the choana and medial to it. Above the fang pair, the bone is quite thick. The vomerine tusks do not touch the mandible since they are placed far from the palatal margin, being separated from it by the internal narial opening.

Between the tusk pairs, the ventral surface of the vomers combined displays a pronounced triangular depression, the apex of which is posterior. This depression receives the enlarged symphysial tusks of the mandible (cf. p. 58) in its anterior part. Posterolaterally, each vomer is in contact with the palatine. In contrast with many rhachitomes, the vomers do not enter into the formation of the anterior margins of the interpterygoid vacuities.

The palatine is a small bone, bounded by the maxilla, anterior portion

of the palatal ramus of the pterygoid, and by the vomer. Posteriorly it touches the ectopterygoid. It forms the posterior and posterolateral borders of the choana. It carries a tusk pair in the vicinity of the narial border, where the bone is quite thick. The palatine tusks are larger and stronger than the vomerine, and the pits accompanying them are much deeper. They are placed directly at the posterior end of the internal narial opening on a somewhat elevated crater, and barely touch the medial surface of the mandible.

The ectopterygoid is the thickest bone of the palate; however, it is slightly thinner laterally than medially. Its tusk and pit are intermediate in size between those on the vomers and palatines, and are directly situated inside of the suture with the maxilla. This bone lies between the maxilla, palatine, pterygoid, and the subtemporal fossa.

The pterygoid of *Parioxys* is its largest palatal element. It is arbitrarily divided, for purposes of description, into a palatal ramus, a central portion at the basipterygoid articulation, and a quadrate ramus.

The palatal ramus of the pterygoid is an essentially flat broad plate of bone, mostly thin, forming the anterior, lateral, and posterolateral margins of each of the interpterygoid vacuities. Despite the large size of the latter, the rami of the two sides almost meet in the middle line, although the details of this area are quite obscure. The anterior portion of each ramus is separated from the adjacent portions of the vomer and palatine by a prominent ridge, parallel to which the suture with these two bones runs. Where the palatal ramus of the pterygoid forms the anterior margin of the subtemporal fossa, it extends posteriorly as a well-developed flange which, as far as the writer is aware, is unparalleled in its degree of development in any of the known typical rhachitomous forms. However, it may be mentioned that *Cacops* has a laterally rather than posteriorly directed flange which forms part of the medial rather than the anterior border of the subtemporal fossa (Williston, 1910; Case, 1911, pl. 17, fig. 2).

The central portion of the pterygoid is a thick, dorsally turned, bony lamella which articulates with the basipterygoid process of the basisphenoid in a narrow immovable joint comparable to that of *Eryops* (Sawin, 1941, pls. 2, 3 and 8 *a*).

The quadrate ramus is an essentially vertical plate which forms the medial border of the subtemporal fossa. It turns upward and proceeds backward to join the squamosal, quadratojugal, and quadrate (plate III, fig. 5), and envelopes the adductor muscle of the lower jaw. This part of the pterygoid is much thicker in the vicinity of the basipterygoid articulation and the border of the adductor fossa than near the quadrate.

The palatal structure of *Parioxys* is rather a unique one, combining primitive, advanced, as well as specialized characters. That the pterygoids reach the vomers anteriorly is primitive; the large size of the interpterygoid vacuities is an advanced character, while the extreme elongation of the internal nares is, as mentioned above, unparalleled among rhachitomes with normally built skulls. The presence of an anterior depression on the vomers for the reception of symphysial tusks on the mandible recalls a similar structure in *Trematops* (Olson, 1941, fig. 8 *a*). As repeatedly pointed out, the general structure of the palate of *Parioxys* is suggestive of that of *Cacops*. However, the sutures are not known in the latter form, and the similarity between the two types cannot be proved or disproved on the basis of the above-given information alone.

E. *Palatoquadrate.*

Of the ossifications of the palatoquadrate arch, only the quadrate (pl. III, fig. 5) is known in *Parioxys*. This is a thick, roughly pyramidal bone which occupies the posteriormost corner of the skull, both on the palatal and dorsal surfaces, and forms the posterior border of the subtemporal fossa. It lies posterior to the quadratojugal and slightly ventral to it, and wedges, for a very short distance, between the latter laterally and the posterior expansion of the quadrate ramus of the pterygoid medially. Its transverse surface for articulation with the articular is doubly convex with a shallow depression running in the middle between the two condyles.

F. *Braincase.*

(Plate III, fig. 6)

The anterior portion of the braincase of *Parioxys,* formed by the sphenethmoid, is high and narrow. There are indications that it was well ossified. Of the posterior constituent elements of the braincase, the basisphenoid is in part cartilaginous. It provides the greater part of the basipterygoid processes (sheathed ventrally by the parasphenoid) for articulation with the upper jaw dermal elements. These are stout, anteroposteriorly short processes that maintain short, fixed, and interdigitating sutures with the pterygoids.

The basisphenoid is ventrally underlain by the parasphenoid, with which it is fused. The body of the parasphenoid is broader posteriorly than anteriorly, and it is likely that it extends laterally to ensheath the basipterygoid process of either side ventrally, anteriorly, and posteriorly, taking part in the articulation with the palate. The parasphenoid carries on its ventral surface a shallow, anteroposteriorly oriented depression, on either side of which the bone forms a thin, wing-like structure, similar to that of *Cacops* (Williston, 1910; Case, 1911, pl. 17, fig. 2).

From between the basipterygoid processes anteriorly, the parasphenoid extends as a thin, narrow cultriform process which separates the two interpterygoid vacuities.

Posterior to the basisphenoid, and partly ventrally ensheathed by the parasphenoid, are the two occipital condyles. These are formed mainly by the exoccipitals, apparently with a slight contribution from the small basioccipital.

It may perhaps be appropriate to mention here, for the lack of a better place, that, although there is no sure way of estimating the exact size of *Parioxys* due to the incomplete nature of the individual skeletons, it is quite probable that it was about the size of a *Trematops,* a *Cacops,* or a *Dissorophus.* This conclusion is based on a comparison of the skull, limbs, and limb girdles of the forms mentioned above. *Parioxys* was a much smaller form than *Eryops.* The skull of the presumably adult individual of the former (M. C. Z. n° 1162 A) is 190 millimeters long, while that of a presumably adult *Eryops* (A. M. N. H. n° 4186, data from Sawin, 1941, p. 410) is 525 millimeters. It should be borne in mind that the length of the skull of an animal is not necessarily an absolute index of its size, since the skull may be disproportionately large or small, compared to the body of the animal as a whole. However, the two measurements given above are suggestive of the difference in size between the two forms, *Eryops* being the larger.

II. Lower Jaw.

(Text figures 3 and 4; Plate II, figs. 1-4)

The mandible of *Parioxys ferricolus* is long and slender. In its anterior part it is more-or-less circular in cross section; posteriorly, however, it is somewhat flattened from side-to-side. The maximum height of the jaw is attained at the level of the coronoid process. Of the bones of the lateral side, only the angular is coarsely sculptured, the sculpture being in the form of elongated pits separated by low ridges. The two rami of the mandible meet in a short sutural symphysis formed mainly by the

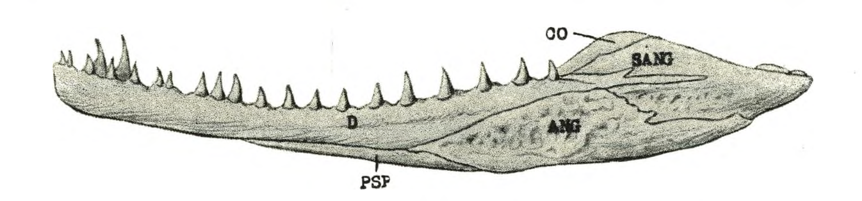


Fig. 3. *Parioxys ferricolus.* Lower Jaw in Lateral View.

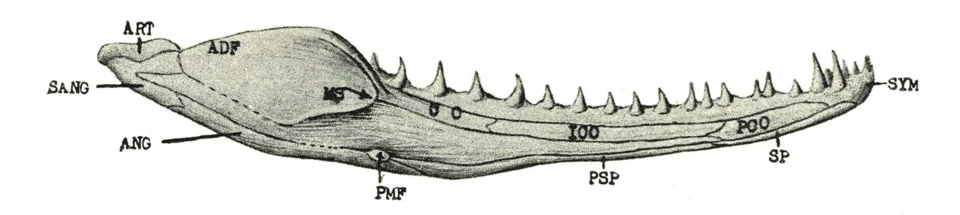


Fig. 4. *Parioxys ferricolus.* Lower Jaw in Medial View.

dentary, with a small ventroposterior contribution from the splenial. The shortness of the symphysis seems to be correlated with the shortness of the skull.

The slenderness of the mandible of *Parioxys* recalls that of *Acheloma* and *Trematops* on one hand (Olson, 1941, figs. 2 B, 3, 5, 6 B, 7 A, C, and 10), and *Cacops* (Williston, 1910; Case, 1911, p. 122, pl. 17, figs. 3, 4) on the other. However, all the bones on the lateral side of the mandibles of these genera are coarsely sculptured; such is not the case in *Parioxys*.

The lower jaw is characteristically rhachitomous. The dentary is the largest element on the lateral side of the mandible. In addition to its major exposure on the lateral side, it has a narrow component occupying the dorsal margin of the medial. Ventrally the dentary is in contact with the splenial and postsplenial; posteriorly it overlaps the angular, and has a wedge-shaped extension that lies dorsal to the surangular. The sculpture on the dentary is very fine, assuming the form of minute pits.

The exact number of teeth on the dentary is not known; an approximate number is around twenty. The teeth alternate with pits in a labyrinthodont fashion; the alternation, however, is not regular. In the anterior portion of the tooth row there may be as many as twelve teeth without any pits between. These teeth seem to belong to two successive generations, as indicated by a slight difference in size, thus demonstrating a distichous method of tooth replacement (Watson, 1926). The teeth are conical, pointed, circular in cross section, and labyrinthine in structure. Those of the same generation are of a more-or-less uniform size throughout the length of the jaw, except at the level of the coronoid and the posterior part of the intercoronoid, where there occur four or five large teeth. There is at least one pair (and possibly two) of fairly large symphysial tusks on each ramus of the lower jaw. Inside the tooth row and extending its whole length is a very shallow groove which is probably the site of origin of the replacement teeth. Its medial boundary is formed by the dorsal edges of the three coronoids.

The splenial and postsplenial occupy the ventral portion of the medial side of the mandible. The exposure of the two elements on this side is extremely narrow, their main body being on the ventral margin. The splenial is the smaller of the two bones. It takes a small part in the formation of the symphysis, but is invisible on the lateral side of the jaw —a condition resulting in the ventral extension of the dentary to occupy all of the anterior portion of the mandibular lateral side. This feature, so far as the writer is aware, is not known in any other rhachitomous labyrinthodont. The medial components of the splenial and postsplenial are overlain by the prearticular. On the medial surface the postsplenial wedges posteriorly between the angular below and prearticular above, and ends at the anterior corner of the posterior meckelian fenestra. Most of the floor of the meckelian space is furnished by the postsplenial.

The angular occupies the ventroposterior portion of the mandible on both the lateral and medial sides. The lateral component is much larger than the medial. The highly sculptured posteroventral angle of the bone extends outward, downward, and backward beyond the ventral margin of the jaw ramus, forming a well-pronounced «angle» characteristic of *Parioxys*. Anteriorly, the lateral division of the angular wedges between the postsplenial below and dentary above. The much less sculptured medial division of the bone forms the posterior part of the wall of the meckelian space and furnishes the ventral rim of the posterior meckelian fenestra.

The medium-sized surangular occupies the posterior dorsal portion of the lateral wall of the mandible. It lies dorsal and slightly posterior to the angular, posterior to the dentary, and is overlain by a wedge-shaped extension of the latter. It forms the lateral wall of the meckelian space. The surangular is fused with the articular, ensheathing it laterally, ventrally, and medially, There is no retroarticular process; however, a number of faint scars indicate the area where the depressor muscle of the jaw was attached.

The prearticular is the largest element on the medial side of the lower jaw. It extends from the articular forward past the adductor fossa right to the suture between the precoronoid and intercoronoid. Its posterior margin forms the ventral rim of the adducter fossa. For much of it lengths the prearticular is overlain dorsally by the coronoid and intercoronoid, and forms the medial wall of the meckelian space. The bone is fused

with the articular which it ensheathes on the medial side of the mandible.

The articular is completely fused with the angular and prearticular as previously pointed out. It carries a transversely oriented glenoid fossa the details of the structure of which are not known.

The denticle-bearing coronoid is a small bone that forms the antero-dorsal margin of the adductor fossa. It is bound by the posterior portion of the medial component of the dentary above and the prearticular below. Its posterior part forms the thick coronoid process. The surangular has a broad contact with the coronoid on the lateral side of the jaw. The intercoronoid is the largest of the coronoid series. It lies dorsal to and overlaps the anterior portion of the prearticular. The middle portion of this bone is swollen out above the average surface of the medial side of the mandible and carries a large number of fairly small coronoid teeth. The precoronoid is the smallest of the coronoids. There is no evidence of the presence of teeth on either this bone or on the coronoid proper. The three bones extend slightly above the level of the medial component of the dentary to form an uninterrupted rim, thus indicating that, in life, the large palatine and ectopterygoid tusks were placed at some distance medial to the mandible.

It should be noted here that the architecture of the mandible of *Parioxys* and the arrangement of its bones resemble in a general fashion those of such a type as *Eryops* (Sawin, 1941, pl. 5). Apart from such basic resemblances, the two genera are quite different in the details of arrangement and relative sizes of the bones, as well as in the slenderness of the jaw of *Parioxys,* the development of a pronounced angular protrusion, and the lack of sculpture from most of the elements on the lateral side of its mandible. As mentioned earlier, the slenderness of the lower jaw of *Parioxys* recalls that of *Cacops* and *Trematops*. Unfortunately, the sutures are completely unknown in the former, and partially known in the latter. It seems possible that the element labelled splenial (SPL) by Oolson (1941, fig. 10) is the postsplenial, and if this be the case, it is worth mentioning that *Trematops* and *Parioxys* are similar in the failure of the splenial to show on the lateral side of the mandible. However, this cannot be definitely proved to be correct until the structure of the medial surface of the lower jaw of *Trematops* is fully known.

III. Vertebral Column.

(Plate III, fig. 1, Plate IV, Plate IX, fig. 2)

Due to the unavailability of a complete vertebral column of one individual of the species under consideration, the account given below is based on a composite one. Naturally, the exact vertebral count in *Parioxys ferricolus* is not known.

Like the rest of the presacral vertebrae, the atlas (plate IX, fig. 2) consists of a neural arch, an intercentrum, and a pleurocentrum. The first two components of this vertebra are fused together. The basal portion of the neural arch is broad, forming the roof of the wide notochordal canal. Extending upward from the arch pedicel is a two-pronged neural spine which is slightly tilted baskward. At the point where each prong joins the arch, there is a small nubbin of bone which probably articulated with a proatlas.

The atlantal intercentrum is dorsoventrally high. On its anterior surface it carries two subcircular concave facets, one on either side of the notochordal canal, for articulation with the occipital condyles. The shape, size, and position of these two facets leave no doubt about the divided nature of the occipital condyles of *Parioxys*. The posterior surface of the intercentrum is concave. On either side of the opening of the notochordal canal it carries a distinct area for articulation with the pleurocentrum. The latter is a paired structure placed quite close to the ventral margin of the intercentrum.

Excluding the atlas, the presacral vertebrae are typically rhachitomous. It is the writer's conviction that the ossification of each intercentral element took place in a complete disk of cartilage, the dorsal part of which failed to ossify in the anterior dorsal region. This is substantiated by the fact that a number of intercentra close to the sacrum show better ossification, with the result that the notochord is completely surrounded with bone. The notochordal canal is wide. That the notochord occupied the whole canal is doubtful; it is more likely that the inner walls of the intercentrum persisted in a cartilaginous condition, and that the notochord occupied only the central portion of the canal. For each intercentrum

there is a pair of diamond-shaped pleurocentra with subparallel edges, one on either side. They extend well down the posterior edges of the intercentra, and it is very likely that a cartilaginous connection joined their dorsal ends.

The neural arches carry well-developed, laterally compressed neural spines, the height of which is approximately half of the distance between the tips of the pre- and post-zygapophyses. The shortness of the spines is correlated with the small size of *Parioxys*. Below the prezygapophyses the neural arches, thick from side to side (mediolaterally), are continuous with the equally thick transverse processes or diapophyses. Even in the anterior portion of the presacral region these exhibit little lateral expansion, and this progressively diminishes posteriorly.

The sacrum of Parioxys consists of two vertebrae (plate IV, fig. 2). The intercentra are complete rings of bone to which the pleurocentra seem to have been fused (the fusion of central elements may occur in certain regions of the vertebral column, *e. g., Dvinosaurus*—Bystrow and Efremov, 1940, fig. 88 A). The neural arches are suturally united to the central elements. Of the two sacral vertebrae the anterior is the larger and stronger. Its laterally projecting transverse processes are stout and anteroposteriorly broad. The first sacral rib articulates with the transverse process as well as the intercentrum and pleurocentrum. The second sacral rib, articulating in the same manner as the first, is smaller and slightly weaker; however, it takes a positive part in the iliac support.

The caudal vertebrae display well-ossified spool-shaped intercentra through which the excentric wide notochrodal canal pierces close to the dorsal margin. Despite this apparent « stereospondylous » development of the intercentra, the pleurocentra are well ossified small blocks of bone (plate III, fig. 1 fourth vertebra from the left) interposed between the tips of the successive neural arches. It is interesting to note that *Parioxys,* of the early Permian, attained a vertebral structure characteristic of the neorhachitomes [1] of the middle and upper Permian, and

[1] The term « neorhachitomous » is used in a strictly descriptive sense, maening vertebrae in which the intercentra form complete rings of bone while the pleurocentra are still present in an ossified or a cartilaginous condition, without any taxonomic implication of any kind.

the Triassic (Bystrow and Efremov, *op. cit.*). Such development, however should not be unexpected, since the posterior presacral as well as the sacral vertebrae show a transition between the « typical rhachitomous » anterior presacral and « neorhachitomous » caudal elements. The neural arches of all caudal vertebrae are small and show very little spine development.

Of the typical rhachitomes, only *Trematops* is known to have complete ring-shaped intercentra (Olson, 1941, p. 168), and *Cacops* and *Dissorophus* to possess two sacral vertebrae (Case, 1911, table VII, pp. 82-83). It is of interest to note that in *Parioxys* there is a combination of the features characterizing these three forms. The pleurocentra and intercentra of the anterior presacral vertebrae of *Parioxys* resemble those of *Eryops* although, naturally, they are smaller in correlation with its small size.

IV. Ribs.

(Plate IV, figs. 4-6)

In the presacral portion of the vertebral column the ribs show a marked and characteristic regional differentiation. The anterior presacral ribs have well-expanded proximal ends finished in cartilage, a condition suggesting that each had a capitulum as well as a tuberculum for articulation with the intercentrum and diapophysis respectively. The shafts are flat and anteroposteriorly expanded, serving for the attachment of the serratus musculature. In the vicinity of the scapula the cartilage-tipped distal ends of the ribs are expanded into fan-shaped bony lamellae, thus providing more sufficient muscular attachment. This distal expansion, which seems to have started in the posterior « cervical ribs », reaches its maximum beneath the pectoral girdle and diminishes posterior to it.

The posterior presacral ribs are single-headed, articulating with the transverse processes of the neural arches. Their thick cylindrical shafts terminate in cartilage without any distal expansion. All the presacral ribs are curved, following the contours of the body. It is postulated that the distally expanded ones are the longest, and that those posterior to them become progressively shorter toward the sacrum.

The first sacral rib (plate VIII, fig. 1 C) has a well-developed antero-posteriorly expanded head (articulating with the diapophysis, intercentrum and pleurocentrum) and a broad, leaf-like thin blade. Between the head and blade there is a thick, sturdy short shaft—or neck.

Caudal chevrons are well ossified, Y-shaped structures, the ventral prongs of which are circular in cross section.

APPENDICULAR SKELETON

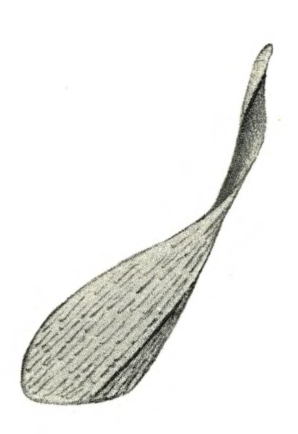
I. Anterior Extremity.

A. *Pectoral Girdle.*

1. *Dermal Shoulder Girdle :*

a) Cleithrum (text fig. 5, plate V, fig. 1).—The bowl of the spoon-





Parioxys ferricolus.

Fig. 5. Left Cleithrum.

Fig. 6. Left Clavicle viewed in the plane of its distal expansion.

shaped cleithrum is narrow from side-to-side, slightly concave medially, and moderately convex laterally. The dorsal part of the cleithrum is turned toward the medial plane of the body, keeping in contact with

the likewise inwardly turned scapular blade. The cleithral shaft [1] is triangular in cross section at its base, the apex of the triangle pointing posteriorly.

The cleithrum of *Parioxys* belongs to the *Eryops-Cacops* type of Nilsson (1939, pp. 16 and 33). The cleithra belonging to this type are described by that author as being « . . . . . lang und schmal, meistens skulpturlos. . . . . ».

b) Clavicle (text. fig. 6, plate V, fig. 5).—The clavicular blade is more-or-less a triangle, the length of which is approximately twice its breadth. Its lateroanterior edge is much thicker than the medial, especially where the shaft and blade join; there, the thickening assumes the form of a pronounced knob. Externally, the clavicular blade bears a sculpture of fairly strong ridges with intervening fine striations. The sculpture radiates out of a center located where the blade joins the shaft. Very little of the latter is known; however, it is quite narrow, and was restored in the same manner as the cleithral shaft.

2. *Primary Shoulder Girdle* (text fig. 7, plate V, fig. 4, plate VI).

The primary shoulder girdle consists in *Parioxys*, as in other rhachitomous amphibians, of a continuous scapulocoracoid plate with a characteristic screwshaped glenoid cavity. At the anterior edge of the glenoid there is a prominent strong ridge which apparently served for the attachment of a ligament that held the humerus in position. Above the glenoid cavity, and forming the anterior portion of its dorsal margin, is a triangular supraglenoid buttress the height of which is half the length of the glenoid. Piercing the buttress in its anterior part is the large oval supraglenoid foramen, the inner opening of which lies in the upper portion of the subcoracoscapular fossa on the inner side of the girdle. The pectoral girdle of *Parioxys* has no glenoid foramen. The posterior border of the supraglenoid buttress is uniformly rounded and thick.

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[1] Restored by estimating the extent of its contact with the anterior border of the scapular blade.

The dorsoventrally expanded scapular blade is slightly curved toward the medial plane of the body following the body contours. It is more expanded in an anteroposterior direction dorsally than ventrally. Its anteriorly slanting upper margin is finished in cartilage. Just above the glenoid the outer surface of the blade is concave; the dorsal part, however, is slightly convex both anteroposteriorly and dorsoventrally. The backward tilt of the posterior border increases dorsally; the anterior border is less backwardly tilted than the posterior. The ventroanterior portion of the outer surface of the scapular blade (which presumably furnished attachment for the scapulohumeralis anterior muscle) is distinctly set off from the dorsal by a low ridge at the level of the dorsal margin of the glenoid cavity.

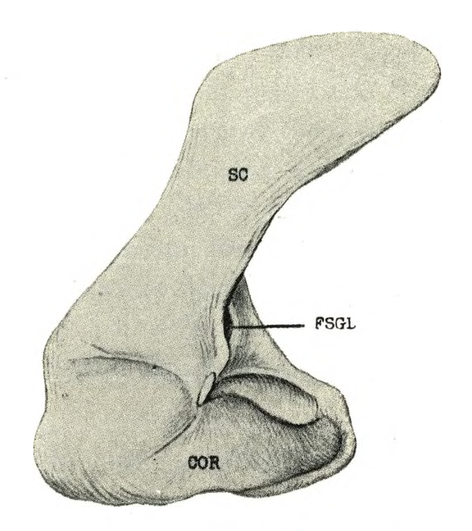


Fig. 7. *Parioxys ferricolus.* Scapulocoracoid.

The outer surface of the scapular blade continues ventrally into the anterior portion of the coracoid region where the supracoracoid muscle presumably had its origin. The anterior margin of this area is well rounded and is finished in cartilage. The coracoid plate continues below the glenoid cavity, ending dorsoposteriorly in a fairly strong process to which the coracoid head of the triceps muscle was presumably attached. The anterior portion of the plate is convex and thin, whereas

the posterior is thick and concave. Just below the glenoid cavity there is a depression housing the outer opening of the coracoid foramen, the inner opening of which lies in the ventral portion of the subcoracoscapular fossa. The ventral border of the coracoid plate, again finished in cartilage, is slightly notched opposite the middle part of the glenoid in those girdles belonging to young adults and young individuals.

It is interesting to note that, as in the case of the cleithrum, the pectoral girdle of *Parioxys* is of the same kind as that of *Dissorophus* (personal observation) and *Cacops* (Case, 1911, pls. 13, fig. 1; and 19, fig. 1). As discussed in a later publication, this type of girdle is characterized by the possession of a large postglenoid region of the coracoid and a broad scapular blade.

B. *Pectoral Limb.*

1. *Humerus* (plate V, figs. 3 and 6; plate VII).

The humerus of *Parioxys* is of the tetrahedral type common to all Paleozoic amphibians, with the proximal and distal ends twisted upon each other, the angle of twist being about 75°. Both the proximal and distal articular surfaces were formed in cartilage. Of the two ends of the bone the proximal is more expanded than the distal. The cancellous bony tissue was generally weak in the young adults of *Parioxys*.

On the proximal dorsal surface of the humerus the areas associated with the attachment of the deltoideus, humeroradialis, scapulohumeralis anterior, lateral head of the triceps, subcoracoscapularis, and latissimus dorsi are very feeble. The distal dorsal surface is separated from the proximal dorsal by a thick and slightly rugose ridge which distally forms the ectepicondyle. One of the most striking features of the humerus of *Parioxys* and related types (to be discussed in a forthcoming publication) is the continuous nature of this ridge, as contrasted with the humeri of *Eryops* (Miner, 1925, fig. 18) and *Trematops* (Olson, 1941, fig. 11 B), in which a ridge is absent and the supinator process is markedly set off from both proximal and distal ends of the bone. In *Parioxys ferricolus,* the supinator process is fused with the ectepicondyle. The entepicondyle is slightly thickened both proximally and distally, and is

finished in cartilage. Apparently, the flexor musculature was well-developed.

The radial articulation is concealed in dorsal view by a downwardly curved distal expansion of the distal surface of the bone. On the other hand, the ulnar articulation is readily seen from the dorsal side, as a result of a crescentic recess of the distal dorsal surface. The distal margin of the humerus is roughly W-shaped with the median prongs very much separated.

The deltopectoral ridge is moderately developed, indicating a moderate development of the pectoralis musculature. The ridge extends distoventrally for a short distance and then fades out rapidly.

The distal termination of the humerus is formed by the cartilaginous articular surfaces for the radius and ulna. The radial articulation is represented in *Parioxys ferricolus* by a shallow concavity situated at the anterior end of the distal margin of the humerus. The ulnar articulation is a concavity that partly shows as a crescent on the dorsal surface. It is divided into two small depressions separated by a slightly elevated ridge.

The humerus of *Parioxys* belongs to the *Cacops* type of Nilsson (1939, p. 28, figs. 6 H, 7 J-K, and 8 C-D), which includes *Cacops, Dissorophus,* and *Buettneria*. In this type the supinator process is feeble, the deltopectoral ridge is weak, the shaft is relatively long, and the two ends of the bone are not quite at right angles to each other.

2. *Radius* (plate V, fig. 2 ; plate IX, fig. 8).

The radius is a more-or-less subcylindrical bone with both proximal and distal ends mediolaterally expanded. The dorsal surface of the bone is convex from side-to-side and slightly concave from end-to-end. The ventral surface, on the other hand, is concave from side-to-side proximally, while the distal end is convex.

The proximal part of the bone is club-shaped, terminating in a slightly concave triangular articular surface. On the lateral side of the proximal part of the radius there is a moderately developed oval swelling that fades out rapidly toward the distal end. This is separated from the ventral margin of the articular surface by a shallow notch.

The distal part of the radius is slightly more expanded and thicker than the proximal. Its distal surface for articulation with the radiale is diamond-shaped ; around the margins of this surface there are faint rugosities associated with the joint capsule tissues and carpal ligaments. The shaft is moderately elongated and is triangular in cross section.

Here again, the radius of *Parioxys* agrees with that of *Dissorophus* (Case, 1911, fig. 45 B) and *Cacops* (*op. cit.*, pl. 23, figs. 7-9) in shape and general proportions. It differs from that of *Eryops* and *Trematops* mainly in proportions. In these genera it is relatively shorter, stouter, and more heavily built. The proximal articular surface of the radius of *Eryops* is subcircular rather than oval (personal observation on M. C. Z. nº 1831), and its distal surface is relatively broader than that of *Parioxys*.

II. Posterior Extremity.

A. *Pelvic Girdle*.

(Text figure 8, Plate VIII, figs. 1 A and B)

As in all normal tetrapods, the pelvis of *Parioxys* consists of the three familiar bones : ilium, ischium, and pubis. The ilium includes the upper

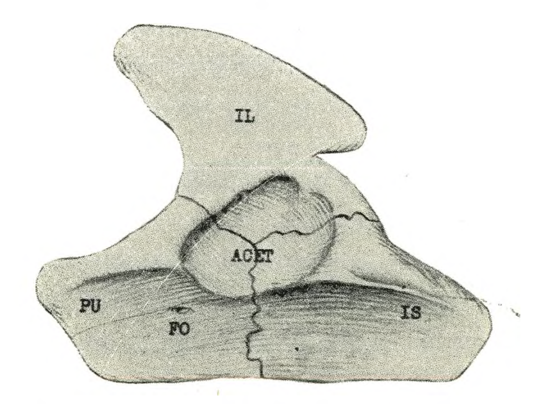


Fig. 8. *Parioxys ferricolus*. Pelvic Girdle.

third of the acetabulum, above which it constricts slightly forming a neck. Beyond the neck it expands again into an anteroposteriorly broad blade. Directly above the acetabulum the ilium is lateromedially thick ;

from this point dorsally, anteriorly, and posteriorly it becomes thinner. Ventrally the ilium is set off from the acetabular cup by an upwardly curved ridge, topped by a pronounced buttress situated in the posterior portion of the iliac neck and bounded behind by a fairly deep notch. At the posterior edge of the blade there is a faint rugosity presumably associated with the attachment of the lateral caudal muscles.

Whether the dorsal limb musculature or the axial muscles occupied the outer surface of the iliac blade is hard to tell, for the lack of the necessary features on this bone to allow such determination.

The inner surface of the ilium is anteroposteriorly concave, particularly in the neck region. The areas for attachment of the two sacral ribs lie a short distance from the dorsal margin of the iliac blade. Opposite the upper part of the acetabular cup the inner surface of the ilium is convex both anteroposteriorly and dorsoventrally.

The acetabulum is roughly oval (slightly broader posteriorly) with the long axis oriented in an anteroposterior direction. It is formed by almost equal contributions from the three constituent elements of the pelvis. The actual articular surface is a triangle the corners of which are the iliac, ischiadic, and pubic angles. In the ischiadic region the acetabular surface faces anteriorly and slightly downwardly, while at the pubic angle it looks backward. The ischiadic angle is a thick pronounced knob. The buttress at the base of the iliac blade is the iliac angle of the acetabulum, and it is assumed to have aided in preventing the dorsal dislocation of the head of the femur.

The puboischiadic plate is almost equally shared between the ischium and pubis. It is anteroposteriorly broad. The pubic portion is more outwardly directed than the ischiadic; thus the outer surface of the plate is slightly concave both anteroposteriorly and dorsoventrally. The posterior portion of the ischium faces slightly forward, resulting in a deep concavity in this part of the pelvis. The dorsal rim of the pubis is uniformly rounded and smooth; that of the ischium is a broad shelf, concave both anteroposteriorly and mediolaterally and facing dorsally and slightly outward. The outer opening of the obturator foramen, piercing the pubis, is much wider than the inner, and lies directly ventral to the pubic angle of the acetabulum. The lower edge of the puboischiadic plate is straight. This, the anterior border of the pubis, and the posterior margin of the ischium are unfinished bony surfaces that were continued in life in cartilage.

The inner surface of the puboischiadic plate is convex in the anterior portion of the pubis (where it presumably gave rise to the anterior puboischiofemoralis internus muscle) as well as in the posteriormost portion of the ischium. In between, it is concave both anteroposteriorly and dorsoventrally. The symphysial union is weak, and was apparently cartilaginous. The symphysial surface extends on both ischium and pubis, with the maximum height in the middle of its length. From this point it diminishes slightly toward the pubic end; toward the ischiadic end, however, it remains constant.

So far as the writer is aware, no other rhachitome is known to possess an ilium so much anteroposteriorly expanded as that of *Parioxys*. However, the ilia of *Cacops* (Williston, 1910; Case, 1911, pl. 22, fig. 1) and *Dissorophus* (personal observation on M. C. Z. material) are moderately expanded in an anteroposterior direction. This feature, together with many others, presented in a forthcoming publication, are the basis for uniting the two families including these three forms into one superfamily.

B. *Pelvic Limb.*

1. *Femur* (plate VIII, figs. 2 and 3).

The femur of *Parioxys* is a slender bone the articular surfaces of which are finished in cartilage. The proximal and distal ends are expanded in an anteroposterior direction, and although a slight twisting of the two ends appears to have taken place, close examination shows that they are in exactly the same plane.

The proximal articular surface is pear-shaped; it is convex both dorsoventrally and anteroposteriorly. Its ventral margin is slightly notched at its middle, marking the proximal expansion of the intertrochanteric fossa. Very feeble rugosities, visible around the head of the femur, are probably for ligamentous attachment. The puboischiofemoralis internus as well as the ischiotrochantericus attachments are still more feeble. The

shaft composes about one third of the length of the femur. The distal expansion of the dorsal surface of the bone is divided into the two articular condyles; these are separated by the intercondylar fossa and notch. The anterior condyle is thicker and broader than the posterior. Its distal surface, articulating with the tibia, is triangular. The distal surface of the posterior condyle is convex both anteroposteriorly and dorsoventrally and carries a small articular facet for the fibula at its posterior angle. The intercondylar fossa extends the distal third of the length of the femur from between the articular condyles proximally. Its greatest depth is between the two condyles, beyond which it extends distally as the intercondylar notch.

The intertrochanteric fossa occupies approximately the proximal fourth of the length of the ventral surface of the femur, presumably housing a portion of the puboischiofemoralis externus muscle. It is bounded anteriorly by a low feeble ridge distal to which there is a small internal trochanter. The adductor ridge starts at the internal trochanter and proceeds distally, crossing the ventral surface of the bone diagonally, and furnishing attachment for a presumably moderately developed ischiofemoralis, or adductor muscle. The maximum height of the ridge is reached at the middle of the shaft of the bone where it is rugose. This rugosity may be suggestive of a feeble development of a fourth trochanter; however, in the absence of a posterior ridge limiting the intertrochanteric fossa, it is more likely that this is not the case. From this rugosity distally, the ridge declines, ending without any bifurcation, and therefore there is no definite popliteal surface.

As in the case of the previously described appendicular skeletal elements, the femora of *Parioxys, Cacops* (Williston, 1910, pl. 13, figs. 2-5), and *Dissorophus* (Williston, 1910 *a;* Case, 1911, pl. 13 fig. 3) look so much alike that they are considered by the present writer as belonging to a « *Cacops*-type» (Moustafa, in press).

2. *Tibia* (plate IX, fig. 4).

The tibia of *Parioxys* is a slender bone, broad above where it carries the surface for articulation with the femur. It has a slim shaft. The bone is relatively long for an amphibian (its estimated length being

approximately 0.6 of that of the femur), a feature which suggests that *Parioxys* was capable of relatively fast motion. The dorsal surface of the tibia carries a moderate cnemial crest.

3. *Fibula* (plate IX, fig. 7).

The distal portion of the fibula is a broad thin bony lamella the medial side of which is strongly concave while its lateral side is almost straight. The distal articular surface is divided into two portions. That for articulation with the fibulare is expanded facing distally and slightly laterally; that for the intermedium is narrow and faces more medially and distally.

4. *Pes* (plate IX, fig. 3).

As far as can be told from the available material, the metatrasals and phalanges are dorsoventrally flattened, hourglass-shaped bones, with concave lateral and medial borders. The phalangeal formula suggested by such material is ?-3-4-3-?. The ossified nature of the tarsalia is a strong indication of the terrestrial habits of Parioxys.

HABITS OF *PARIOXYS*

The structure of *Parioxys* suggests that it was a form well adapted for terrestrial life. The skeleton is well ossified for an amphibian. The skull is moderately high, the orbital openings face laterally and slightly dorsally, there are no traces of lateral line grooves on the skull or lower jaw, and the pubis and tarsalia are very well ossified.

The limb bones are long and slender, and although *Parioxys* is a small form, their slenderness is not to be attributed entirely to that. The presence of two sacral ribs providing a better iliac support is an indisputable evidence that *Parioxys* was an active land dweller. Further support to this conclusion is provided by the relative length of the lower leg elements. The length of the radius is 0.82 of that of the humerus, while that of the tibia is approximately 0.6 of the length of the femur. These ratios seem to be relatively high for an amphibian, and suggest that *Parioxys* was capable of fast locomotion.

MEASUREMENTS OF THE SKULL

Since there is no standard system of measurement of amphibian bones, the following procedure was pursued in obtaining the figures given in the ensuing table :

1. The length of the skull and the four segments into which it is broken is taken between perpendiculars to the mid-line.

2. The width of the skull is taken along perpendiculars to the mid-line.

The following symbols are used in the table of skull measurements :

av = average of the measurements of the two sides ; est = estimated ; def = deformed ; inc = incomplete.

Table I Skull

a. A.M.N.H. n° 4309, holotype (Moustafa, 1952, pls. I-III, fig. 1).
b. A.M.N.H. n° 2445 (Moustafa, *op. cit.*, pls. I-III, fig. 2).
c. M.C.Z. n° 1162 (plates I-II).

All measurements are in millimeters :

	a	*b*	*c*
Length to quadrate	107	115(inc)	190
Length to posterior margin of table	84	92	147
Length to anterior border of orbit	48	53	92
Length to posterior border of nostril	21	?	26
Length posterior to orbit	21	21	24
Width between posterolateral corners of nostrils	16.5	15.5	21
Width between orbits (at the level of suture between frontal and parietal)	21	14(def)	30
Width between tabular horns	35	40(est)	66
Width between outer borders of quadrates	56	?	135(est)
Maximum width of skull	76(est)	73	137
Diameter of orbit anteroposteriorly	25(av)	25(av)	39
Diameter of orbit transversely	22(av)	21	37

Table II Lower Jaw

a. Mandible associated with skull A.M.N.H. n° 4309, holotype.
b. — — — A.M.N.H. n° 2245.
c. — — — M.C.Z. n° 1162 A.

	a	*b*	*c*
Length to articular	107	103	178
Length to « angle »	89	89	120
Length of dentary	?	?	162
Length of symphysis	?	9	21
Height of « angle »	18 (def)	?	26

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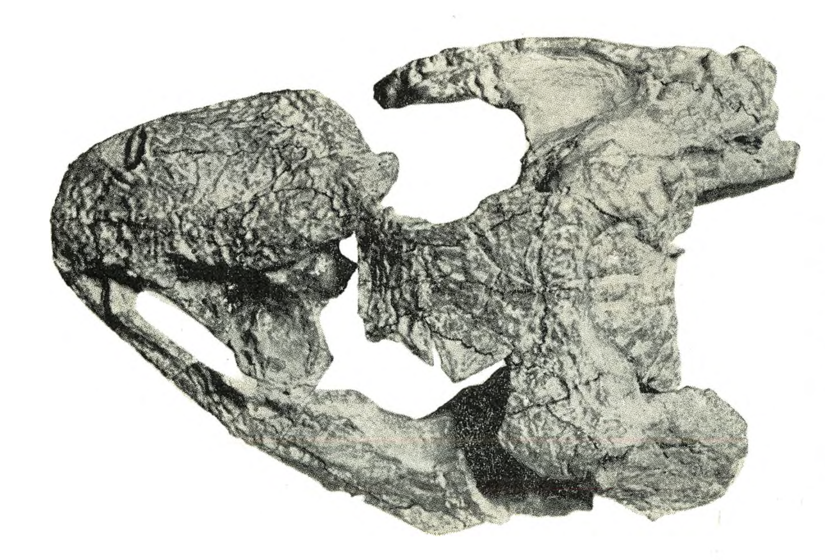
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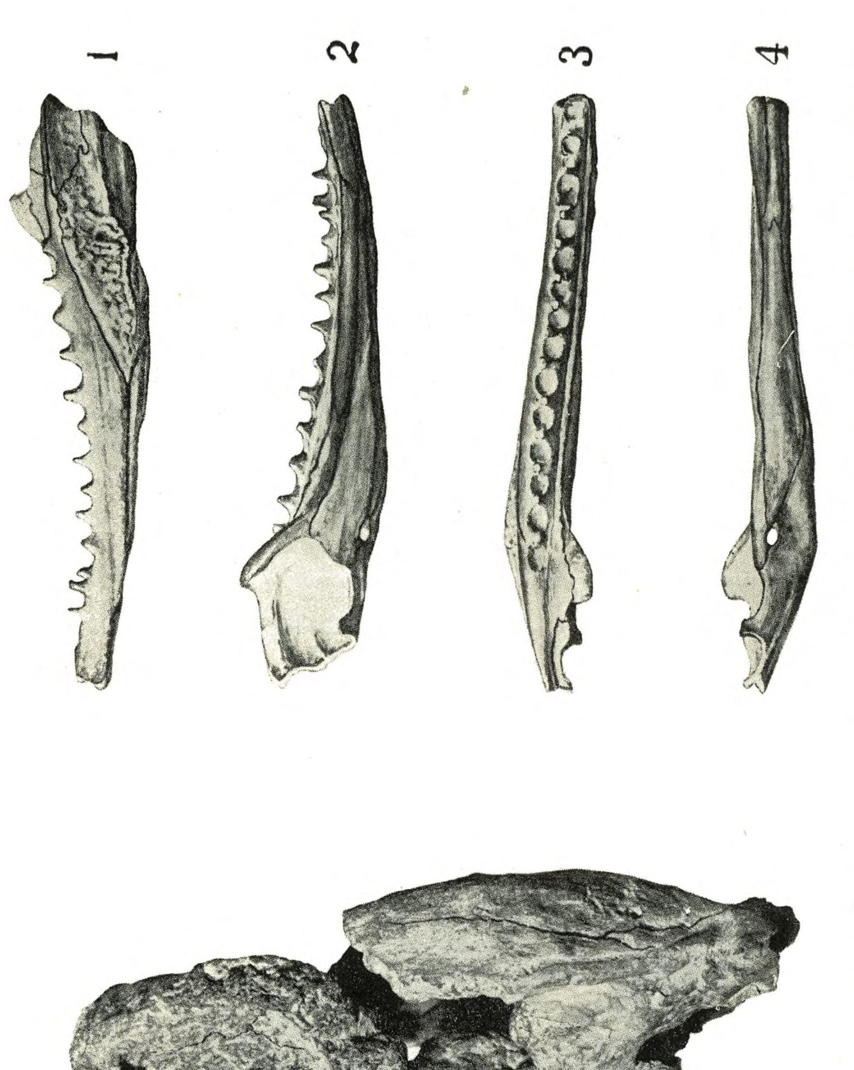
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Parioxys ferricolus : M.C.Z. n° 1162 A.
Skull of a presumably adult individual in palatal view.



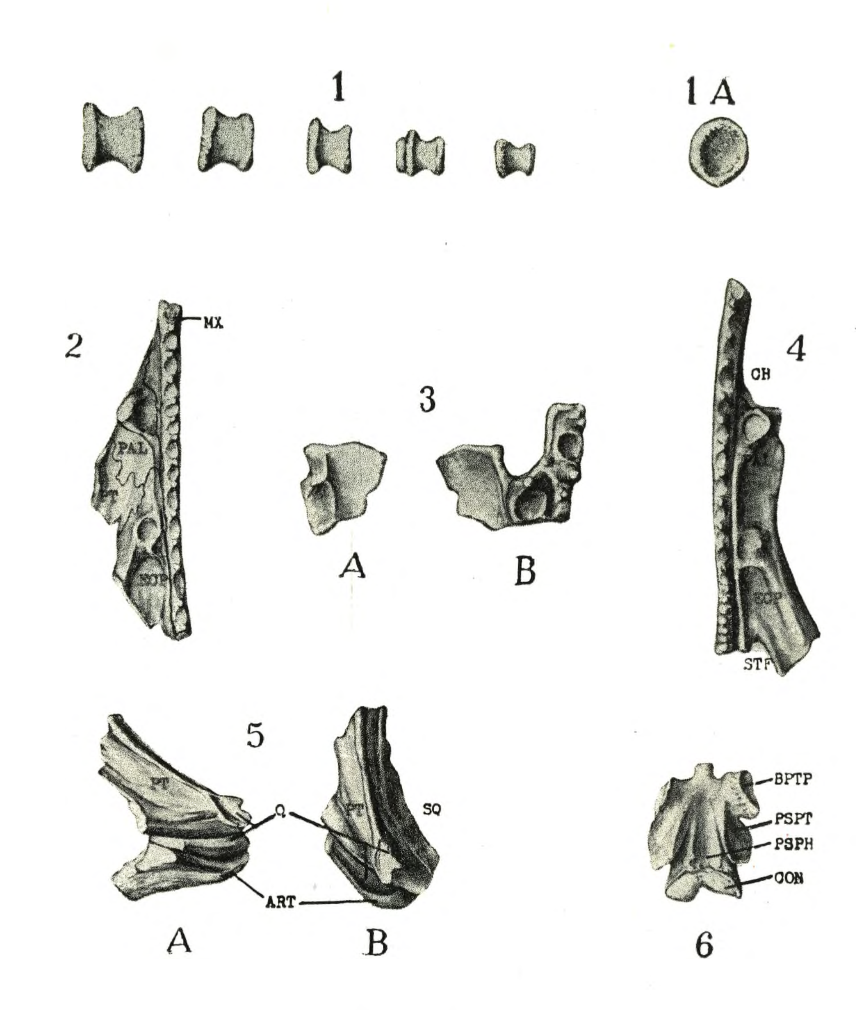
Parioxys ferricolus : M.C.Z. n° 1162 A.
Skull of a presumably adult individual in dorsal view.



Parioxys ferricolus : M.C.Z. n° 1162 D. Left mandible of a young adult.

Fig. 1.—Lateral view.
Fig. 2.—Medial view.
Fig. 3.—Dorsal view.
Fig. 4.—Ventral view.

Parioxys ferricolus : M.C.Z. n° 1162 A. Skull and mandible of a presumably adult individual in side view.



Parioxys ferricolus

Fig. 1.—A number of caudal vertebrae.
1 A End view of intercentrum.

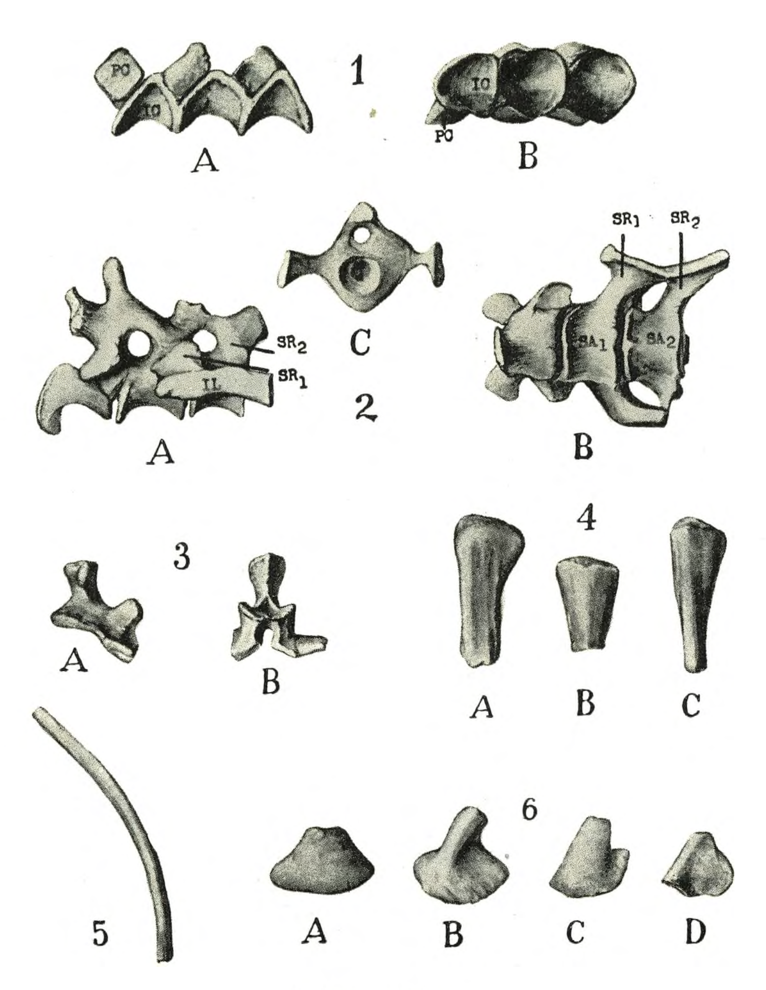
Fig. 2.—Partial palate M.C.Z. n° 1162 D'.

Fig. 3.—A portion of the vomer and palatine of the left side.
A. Dorsal view. B. Ventral view.

Fig. 4.—Partial palate, M.C.Z. n° 1162 H.

Fig. 5.—Quadrate region of the skull.
A. Medial view. B. Posterior view.

Fig. 6.—Parasphenoid in ventral view.



Parioxys ferricolus

Fig. 1.—Three anterior presacral vertebrae (the neural arches are omitted) :
A. Side view. B. Ventral view.

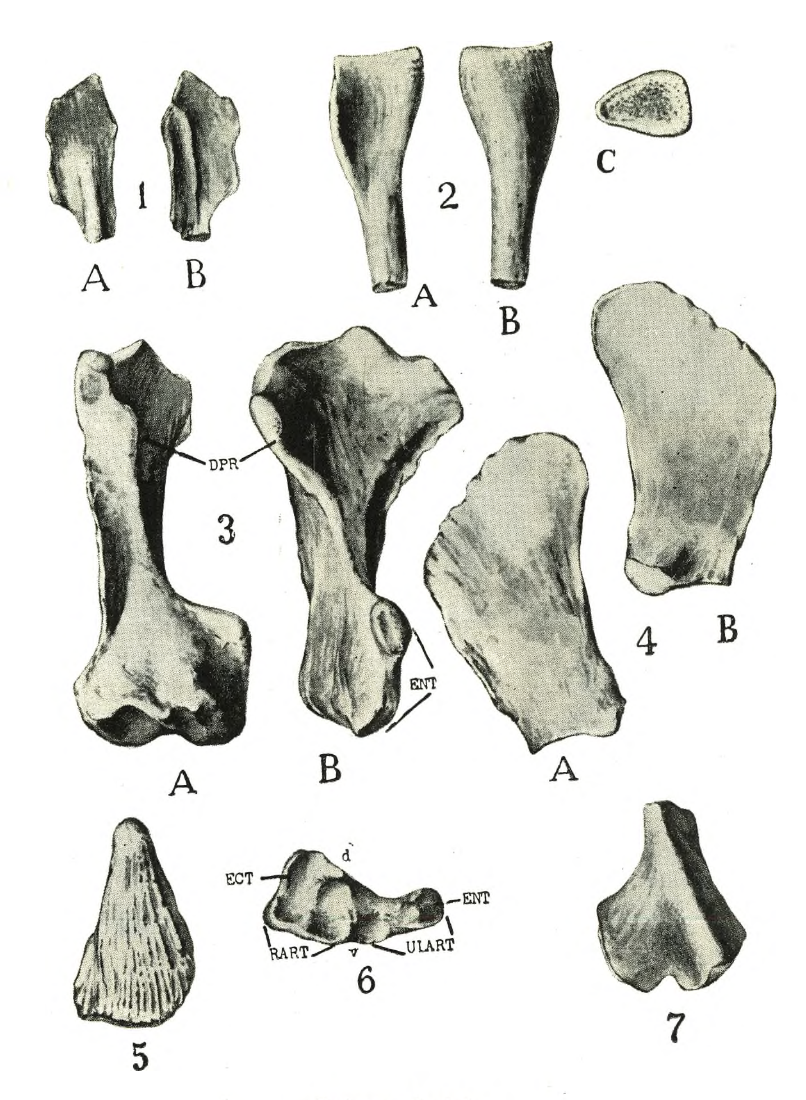
Fig. 2.—The last presacral and the two sacral vertebrae.
A. Side view. B. Ventral view.
C. Posterior view of the second sacral.

Fig. 3.—Neural arch of a posterior presacral with a single-headed rib in position.

Fig. 4.—Proximal portion of three ribs. Note the diminution of the anteroposterior expansion from A (anterior presacral) to C (close to the sacrum).

Fig. 5.—Rib shaft.

Fig. 6.—Distal portions of « dorsal» ribs. Note the diminution of the distal rib lamella from A to D (in the direction of the sacrum).



Parioxys ferricolus

Fig. 1.—Left cleithrum :
A. Lateral view. B. Medial view.

Fig. 2.—Radius :
A. Dorsal view. B. Ventral view.
C. Proximal articular surface.

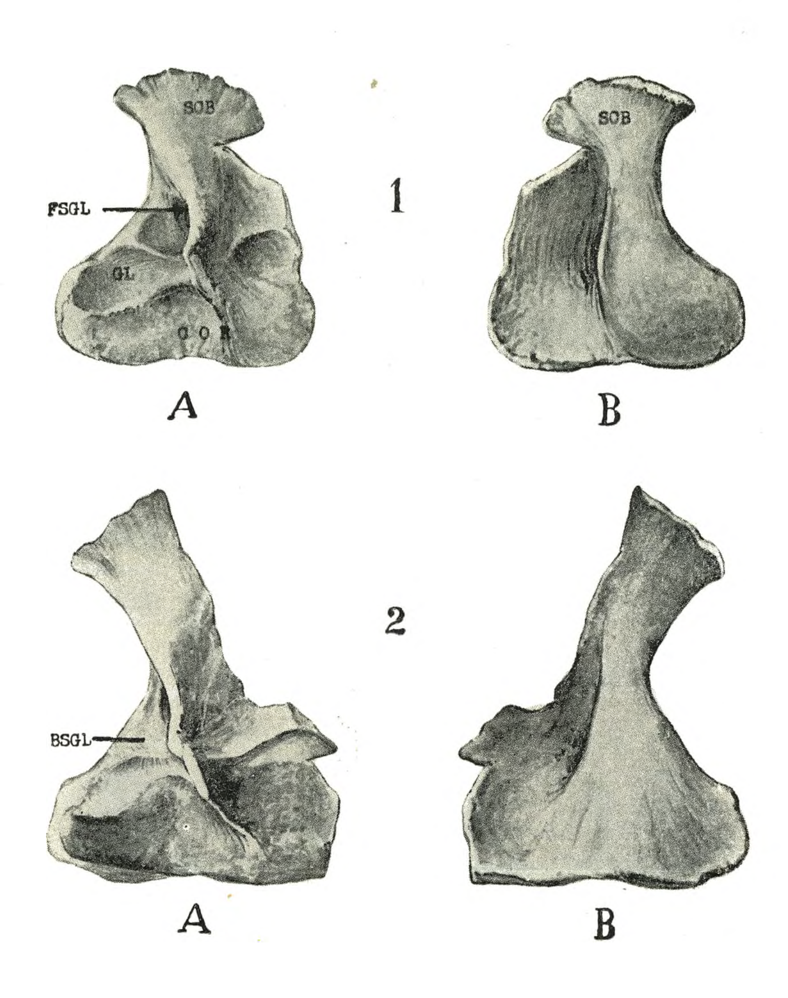
Fig. 3.—Right humerus in ventral view.
A. Distal surface. B. Proximal surface.

Fig. 4.—Scapular blade of an adult individual.

Fig. 5.—Clavicular blade.

Fig. 6.—Distal articular surface of the humerus.

Fig. 7.—Distal portion of the right humerus of a young individual in dorsal view.



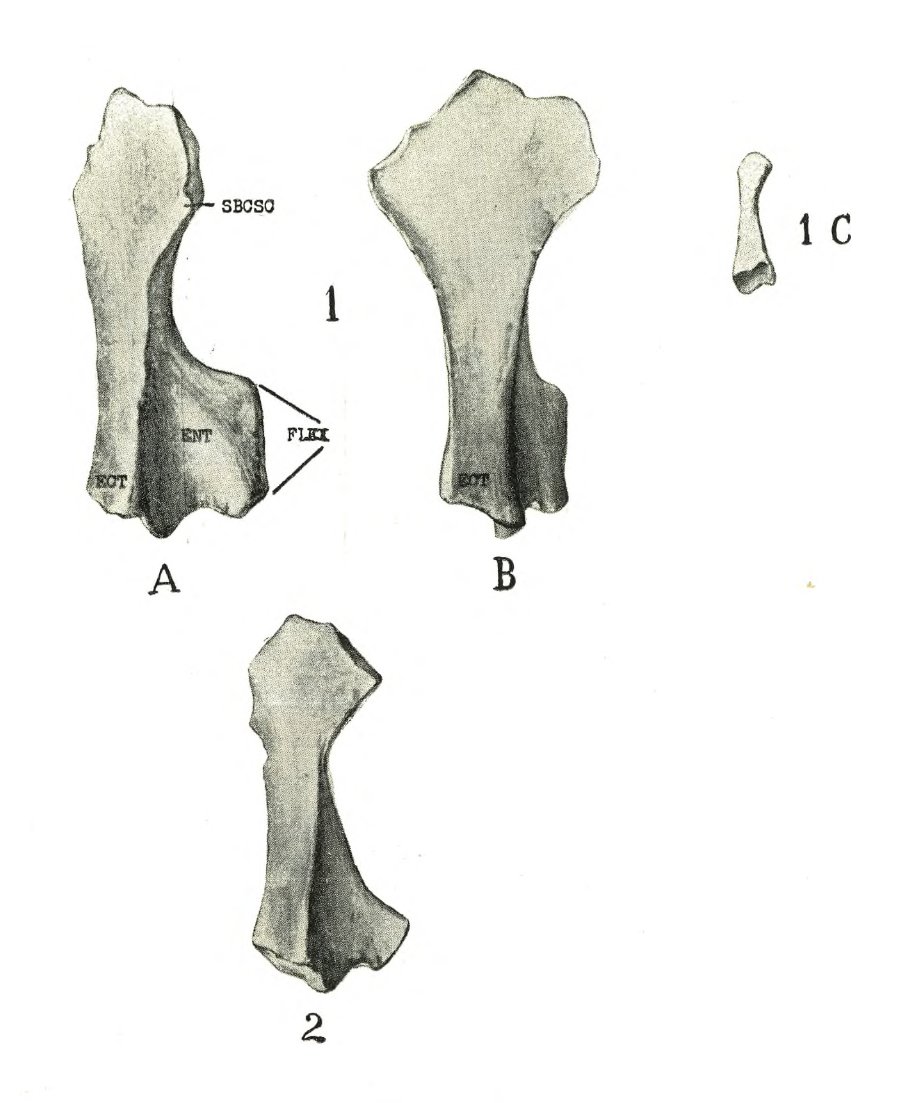
Parioxys ferricolus

Fig. 1.—Scapulocoracoid plate of a young adult individual.

A. Lateral view. B. Medial view.

Fig. 2.—Scapulocoracoid plate of an adult individual.

A. Lateral view. B. Medial view.



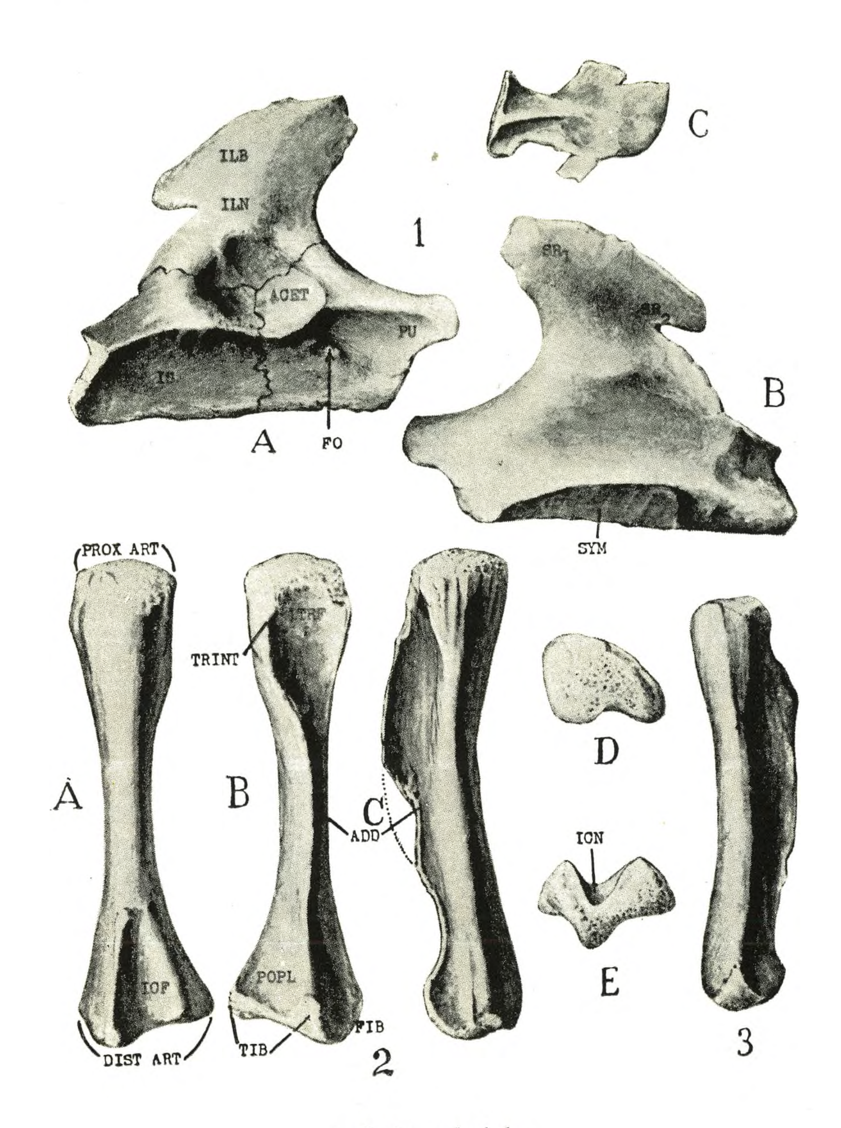
Parioxys ferricolus

Fig. 1.—Left humerus of an adult individual in dorsal view.

A. Distal surface. B. Proximal surface.

C. Entepicondylar margin.

Fig. 2.—Left humerus of a presumably very young individual.

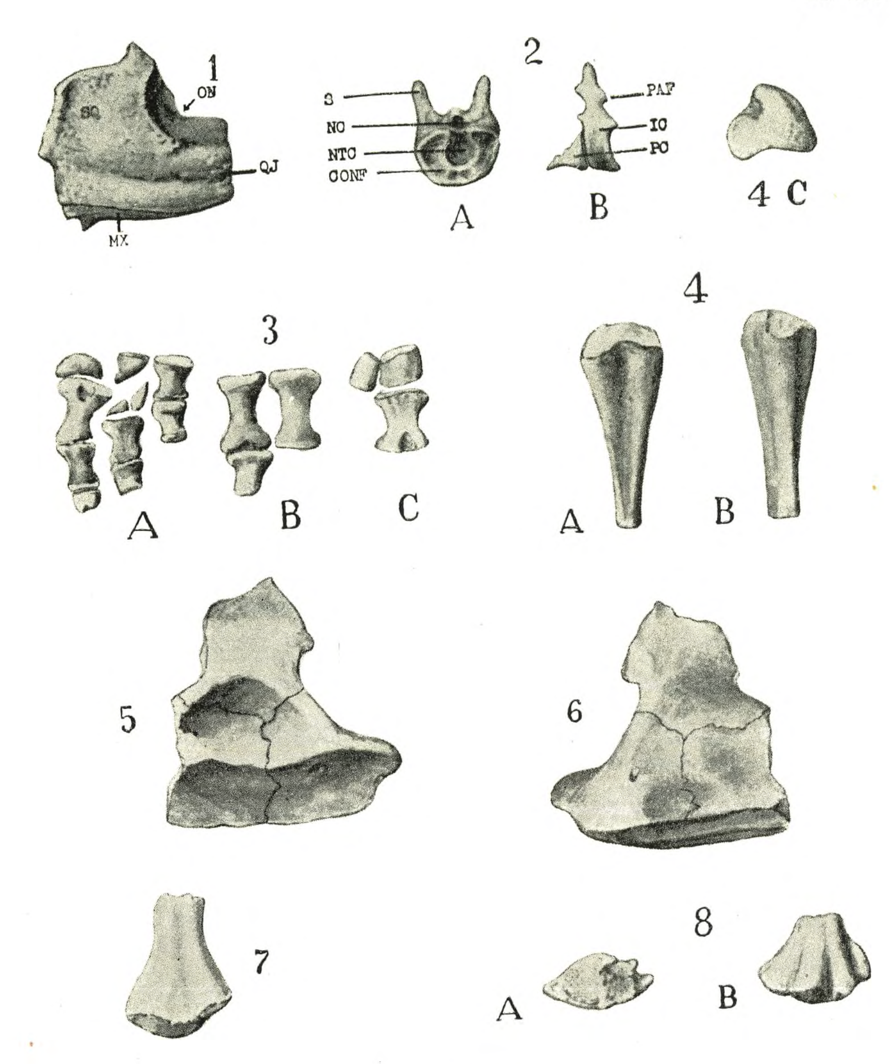


Parioxys ferricolus

Fig. 1.—Pelvis
A. Lateral view of the right side.
B. Medial view of the right side.
C. First left sacral rib.

Fig. 2.—Right femur of an adult individual.
A. Dorsal view. B. Ventral view.
C. Lateral view.
D. Proximal articular surface.
E. Distal articular surface.

Fig. 3.—Left femur of a presumably young individual in side view.



Parioxys ferricolus

Fig. 1.—Posterior portion of cheek and temporal region of skull showing the otic notch.

Fig. 2.—Atlas vertebra.
A. Anterior view. B. Lateral view.

Fig. 3.—Various elements of foot material.

Fig. 4.—Proximal part of the left tibia of an adult individual.
A. Dorsal view. B. Ventral view.
C. Articular surface.

Fig. 5.—Right half of the pelvic girdle of a young adult individual in lateral view.

Fig. 6.—Right half of the pelvic girdle of a young adult individual in medial view.

Fig. 7.—Distal portion of the fibula of an adult individual.

Fig. 8.—Distal portion of the radius of an adult individual.

ABBREVIATIONS USED IN THE ILLUSTRATIONS

ACET acetabulum.
ADF adductor fossa.
ANG angular.
ART articular.

BSGL supraglenoid buttress.
BPTP basipterygoid process.

CH choana.
CO coronoid.
CON occipital condyle.
CONF occipital condyle facet on the atlas.
COR coracoid.

D dentary.
d dorsal.
DIS ART distal articular surface.
DPR deltopectoral ridge.
DVA vomerine anterior depression.

ECP ectopterygoid.
ECT ectepicondyle.
ENT entepicondyle.

FIB fibular articular surface.
FLEX flexor musculature attachment.
FO obturator foramen.
FR frontal.
FSGL supraglenoid foramen.

GL glenoid cavity.

IC intercentrum.
ICF intercondylar fossa.
ICN intercondylar notch.
ICO intercoronoid.
IL ilium.
ILB ilica blade.
ILN iliac neck.
INP internasal pit.
IPV interpterygoid vacuity.
IS ischium.
ITRF intertrochanteric fossa.

JU jugal.

LA lacrimal.

MS meckelian space.
MX maxilla.

NA nasal.
NC neural canal.
NTC notochordal canal.

O orbit.
ON otic notch.

PA prearticular.
PAF proatlas articular facet.
PAL palatine.
PAR parietal.
PC pleurocentrum.
PCO precoronoid.
PMF posterior meckelian foramen.
PMX premaxilla.
PO postorbital.
POF postfrontal.
POP postparietal.
POPL popliteal area.
PRF prefrontal.
PROX ART proximal articular surface.
PSP postsplenial
PSPH parasphenoid.
PSPT parasphenoid tubera.
PT pterygoid.
PU pubis.

Q quadrate.
QJ quadratojugal.

RART radial articular surface.

S neural spine.
SA sacral vertebra.
SANG surangular.
SBCSC subcoracoscapularis attachment.
SC scapula.
SCB scapular blade.
SMX septomaxilla.
SP splenial.
SQ squamosal.
SR sacral rib.
ST supratemporal.
STF subtemporal fossa.
SYM symphysis.

TA tabular.
TIB tibial articular surface.
TRINT internal trochanter.

ULAR ulnar articular surface.

V ventral.
VO vomer.

THE AFFINITIES OF *PARIOXYS FERRICOLUS* AND THE PHYLOGENY OF THE "ERYOPSOID" AMPHIBIANS [1]

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INTRODUCTION

Through the most appreciated courtesy of Professor Alfred S. Romer, Director of the Museum of Comparative Zoology at Harvard University, U. S. A., the writer had the opportunity to study the obscure rhachitomous amphibian *Parioxys ferricolus* (Moustafa, 1950, 1952, 1952 *a*, and in press). On the ensuing pages, an interpretation of the skeletal structure of this form (Moustafa, in press) is attempted, and the possibilities of *Parioxys's* belonging to the hitherto-known fossil amphibian groups are considered.

Although anticipating later discussion, the writer may here note that *Parioxys* is a rhachitome so different from all known Permian forms that a new family—the Parioxydæ—closely related to the Dissorophidæ, should be erected for its accommodation. It has also been attempted to modify the current views on the phylogeny and taxonomy of the eryopsoid amphibians in the light of an analysis of the postcranial structure of the forms involved.

I. INTERPRETATION OF THE STRUCTURE OF *Parioxys*

By virtue of its vertebral structure (Moustafa, in press), *Parioxys* is an apsidospondyl (Romer, 1947, p. 9). Labyrinthine teeth, together

[1] Communication présentée en séance du 7 décembre 1953.

with the formation of the centra of pleuro- and inter-central components, are typical of the Labyrinthodontia [1], to which group *Parioxys* evidently belongs. Since the pleurocentra are paired diamond-shaped structures, the genus is definitely a member of the Temnospondyli. This conclusion is further supported by the presence in *Parioxys* of such palatal features as the broad vomers widely separating the posteriorly situated choanae, and such skull roof features as the posterior position of the widely separated external nares, the firm union of the cheek and skull table, the small size of the tabulars, and their lack of contact with the parietals (Moustafa, *op. cit.,* figs. 1, 2).

That *Parioxys* belongs to the Ichthyostegalia (Romer, 1947, p. 16) is readily ruled out, since the array of primitive features diagnostic of that group is wanting in this form (Watson, 1929, pp. 227-229, figs. 5, 6; Romer, 1930, pp. 100-114, figs. 8-16; Steen, 1931, pp. 852-860, figs. 1-7, pls. 1 and 2; Säve-Söderbergh, 1932; Westoll, 1938; Romer, 1941, fig. 4; Westoll, 1943 and Romer, 1947, p. 91). Moreover, such characteristic specialization as the separation of the postfrontal and supratemporal by the parietal is not known to exist in *Parioxys* (cf. Moustafa, *op. cit.,* fig. 1).

The nature of the basipterygoid articulation bars *Parioxys* from the Trematosauria (Watson, 1919, figs. 23, 25; Säve-Söderbergh, 1936, figs. 4 *a*, 5, 33, 34, etc.; Sushkin, 1927, figs. 5 *c*, 7-10). In addition, the skull of *Parioxys* is relatively depressed, broad, and not so much elongated as, for example, in *Aphaneramma* (Säve-Söderbergh, 1936, figs. 33, 34; 1937, figs. 5, 6), and there is no development of a retroarticular process in the lower jaw (Nilsson, 1943, figs. 2-9, pl. 4, figs. 1-4). Moreover, the large number of small palatal teeth on the vomers, palatines, and ectopterygoids characteristic of the trematosaurs (Haughton, 1915, pl. 2; Watson, 1919, p. 41, fig. 25) are wanting in *Parioxys,* the quadrates of which are far behind the level of the occiput.

[1] The taxonomic term « *Labyrinthodontia* » (Owen) is used here, following Watson (1919, 1926, 1929, 1940), Kuhn (1932, 1939, 1939 *a*), and Romer (1930, 1945, 1947), to include the *Temnospondyls and Anthracosaurs,* as defined by Romer (1947, pp. 311 and 318 respectively).

Parioxys cannot by any means be included in the Stereospondyli [1], since, although the intercentra are developed into complete rings of bone in the sacral and caudal regions of the vertebral column, the pleurocentra are very well developed, and all the known presacral vertebrae are of typically rhachitomous construction. In almost every respect, *Parioxys* is different from the Stereospondyli (cf. Huene, 1932, fig. 7, p. 215; Broili and Schroeder, 1937, fig. 12; 1937 *a*, figs. 1, 3 and 9; Bystrow and Efremov, 1940, figs. 4, 16, 30, and Romer, 1947, figs. 37-40).

Parioxys is referred to and included in the Suborder Rhachitomi, since its presacral vertebrae consist of moderately developed paired pleurocentra and crescentic intercentra, the skull is slightly flattened, the skull table is moderately elongated, the facial region of the skull is well developed, the jaw articulation is far behind the level of the occipital condyles, there is no retroarticular process in the lower jaw, and there is a pair of strong palatal teeth on each of the vomers, palatines, and ectopterygoids.

Included in the Rhachitomi, as a Suborder, *fide* Romer (1947, pp. 311-314), are five Superfamilies : Loxommoidea, Edopsoidea, Trimerorhachoidea, Mircopholoidea, and Eryopsoidea. The Loxommoidea, characterized by the retention of an intertemporal and by the possession of a closed palate, a single occipital condyle, and keyhole-shaped orbital opening (Watson, 1929, figs. 13-22; Romer, 1930, pp. 119-126, figs. 20, 21; 1947, p. 312), cannot accommodate *Parioxys,* in which, beside the absence of an intertemporal, there are wide interpterygoid vacuities, double occipital condyles, and normally built orbits.

The rhachitomous amphibians included in the Superfamily Edopsoidea are markedly different from *Parioxys.* Beside retaining an intertemporal they have a single occipital condyle and a movable articulation between braincase and palate (Romer and Witter, 1942). It is worth

[1] Included in the *Suborder Stereospondyli* are the *Rhinesuchoids, Benthosuchids, Capitosaurids, Brachyopids, Plagiosaurs,* and *Metoposaurs* (Romer, 1947, pp. 315-317).

mentioning that in *Cochleosaurus* (Broili, 1905, pl. 2, fig. 3; Steen, 1938, fig. 30) the internal nares are elongated, the interpterygoid vacuities are enlarged, and the condyle is double, as in *Parioxys;* but the fundamental difference in braincase articulation outweighs these similarities, which are apparently due to parallelism in development. The same holds true for the choanae and palatal vacuities of *Dendrerpeton* (Steen, 1934, figs. 3 and 4), in which the condyle is, however, still single.

It is not possible to include *Parioxys* in any of the families constituting the Superfamily Trimerorhachoidea which are characterized by the possession of a movable basal articulation and a single occipital condyle. Moreover, the quadrates are quite close to the level of the occiput, and there are rows of palatal teeth connecting the tusk pairs (cf. Case, 1935, fig. 2, p. 231, for *Trimerorhachis;* Bystrow, 1938, fig. 1, p. 214, fig. 5 *b*, p. 226, for *Dvinosaurus*, which incidentally, has an almost divided occipital condyle). The secondary elongation of the skull table and shortening of the face are features not encountered in *Parioxys*.

The superfamily Micropholoidea is apparently a synthetic group of rhachitomes including normal-skulled forms (Families Lysipterygiidæ and Micropholidæ), others with long skulls and broad muzzles (Family Chenoprosopidæ), and finally forms with very long skulls and pointed snouts (Family Archogosauridæ). That any of those families is suited to include *Parioxys* is quite difficult to accept, since, apart from the difference in skull configuration (variable as it is in the four families), the movable basal articulation and the single occipital condyle invariably met with in the micropholoids are absent in this form (cf. *Lysipterygium*—Branson, 1935, fig. 2, pl. 1, fig. 1; *Micropholis*, with a tripartite condyle—Watson, 1913; Broili and Schroeder, 1937; *Chenoprosopus*, though incompletely known—Mehl, 1913; Williston, 1918, fig. 7; *Platyops*—Efremov, 1933; Bystrow, 1935, figs. 26, 32 *a*).

The group of rhachitomes closest to *Parioxys* is that referred to by Romer (1947) as the «Superfamily Eryopsoidea». In agreement with that group, *Parioxys* possesses a fixed but narrow basipterygoid articulation, double occipital condyles, moderately enlarged interpterygoid

vacuities, strong paired tusks on each of the vomers, palatines and ectopterygoids, and quadrates situated behind the level of the occiputt [1].

II. Comparison of *Parioxys* with *Eryops*

The writer here proposes to prove that *Parioxys* and *Eryops* are generically distinct, in accordance with the suggestions made by Case (1911, p. 33), Watson (1919, p. 4), and Romer (1936, p. 87; 1947, p. 167).

The skull structure of *Parioxys* is compared with that of *Eryops* as described by Sawin (1941), and text figure 1 is a reproduction of the dorsal view of the skull of *Eryops* (after that author), side by side with that of *Parioxys* (Moustafa, in press).

As regards the postcranial skeleton of *Eryops*, there has been no adequate account in the paleontological literature [2]. Consequently, the vertebral column and appendicular skeleton of *Parioxys* were compared with those of *Eryops* in the Museum of Comparative Zoology collection of fossil amphibians [3]. In order to avoid unnecessary repetition and loss of objective, the comparison is given in a tabular form.

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(1) The definition of this superfamily is based on skull structure only without taking the postcranial into account. Were the latter taken into consideration, it becomes apparent that one is dealing with two superfamilies, not one (cf. pp. 96-100).

(2) Professor A. S. Romer has, in a very early stage of preparation, such an account, which he kindly made available to the writer.

(3) The specimens examined are listed below (M. C. Z. = Museum of Comparative Zoology):

Specimen	M.C.Z. n°	Specimen	M.C.Z. n°
Anterior presacral vertebrae	1904	Radius	1143,1831
Posterior presacral vertebrae	1907	Pelvis	1219
Ribs	1884	Femur (young)	1720
Scapulocoracoid (young)	1900	Tibia (young)	1720
Humerus	1904	Femur (adult)	1586
		Tibia (adult)	1680,1818

Eryops megacephalus.
Skull in Dorsal View
(After Sawin).

Fig. 1

Parioxys ferricolus.
Skull in Dorsal View.

Parioxys	*Eryops*
1. Skull is small and high.	1. Skull is large and flat.
2. Skull is subtriangular.	2. Skull is subrectangular.
3. Orbits are relatively large.	3. Orbits are relatively small.
4. There is one faint ridge on either side of the skull roof.	4. There is an elaborate system of ridges on the skull roof.
5. Parietal foramen is oval and lies between the orbits.	5. Parietal foramen is round and lies posterior to the orbits.
6. Otic notches are large.	6. Otic notches are small.
7. Anterior margin of the muzzle is upwardly arched.	7. Anterior margin of the muzzle is not upwardly arched.
8. There is an internasal pit.	8. There is no internasal pit.
9. Septomaxilla is small.	9. Septomaxilla almost closes the external naris.
10. Nasals are broader posteriorly than anteriorly.	10. Nasals are broader anteriorly than posteriorly.
11. There is no internasofrontal.	11. There is an internasofrontal.
12. Parietals are larger than frontals.	12. Frontals are larger than parietals.
13. Supratemporal does not reach the margin of the otic notch.	13. Supratemporal reaches the margin of the otic notch.
14. There is only one group of large marginal teeth in the upper jaw.	14. There are two groups of large marginal teeth in the upper jaw.
15. Vomers have an anterior median depression.	15. Vomers have a posterior median depression.
16. Internal nares are excessively elongated.	16. Internal nares are of normal shape.
17. Parasphenoid bears two « wings »[1].	17. Parasphenoid has no « wings ».
18. Interpterygoid vacuities are large.	18. Interpterygoid vacuities are smaller.
19. Lower jaw is slender, with a prominent « angle ».	19. Lower jaw is deep, with a rounded posterior margin.
20. Only the angular is heavily sculptured.	20. All lateral bones of the mandible are heavily sculptured.
21. Splenial does not show laterally.	21. Splenial shows slightly on the lateral side.
22. There is no mandibular foramen.	22. Mandibular foramen pierces through postsplenial.

[1] The « basisphenoidal tubera » of some authors (*e. g.*, Romer, 1947, p. 44). Since these processes or wings are parts of the parasphenoid and not of the basisphenoid, the writer is inclined not to use this term. It may perhaps be more appropriate to call these structures the « tubera parasphenoidales ».

Parioxys	*Eryops*
23. Posterior meckelian foramen pierces between postsplenial and angular.	23. Posterior meckelian foramen pierces through the angular.
24. Intercoronoid is the largest of the three coronoids.	24. Precoronoid is the largest of the three coronoids.
25. The largest mandibular teeth are at the level of the suture between pre- and inter-coronoid.	25. The largest mandibular teeth are at the level of the pre-coronoid.
26. There are two sacral vertebrae.	26. There is one sacral vertebra.
27. Caudal and sacral vertebrae have ring-shaped intercentra.	27. Intercentra are crescentic throughout the whole column [1].
28. Pleucentra extend well down the posterior margins of the intercentra.	28. Pleurocentra are higher in position.
29. Ribs are without «uncinate processes» throughout the column.	29. Ribs have «uncinate processes» in the anterior dorsal region.
30. The coracoid region ventral to the glenoid cavity is large.	30. The coracoid region ventral to the glenoid cavity is quite small.
31. Humerus is long and slender.	31. Humerus is short and broad.
32. Processes for muscular attachment on the humerus are feeble.	32. Processes for muscular attachment on the humerus are strong.
33. Proximal and distal dorsal surfaces of the humerus are more-or-less flat.	33. Proximal and distal dorsal surfaces of the humerus are concave.
34. Supinator process is feeble.	34. Supinator process is well developed.
35. Articular surface of the radius is triangular.	35. Articular surface of the radius is oval.
36. Radius is long and slender, with a long shaft.	36. Radius is short with a stout shaft.
37. Iliac blade is anteroposteriorly expanded.	37. Iliac blade is dorsoventrally expanded.
38. Acetabulum is in the middle of the length of the puboischiadicplate.	38. Acetabulum is in the anterior part of the puboischiadic plate.
39. Puboischiadic plate is dorsoventrally broad.	39. Puboischiadic plate is dorsoventrally narrow.
40. Obturator foramen opens on the lateral and medial sides of the pubis.	40. Obturator foramen opens on the lateral side and anterior rim of the pubis.
41. There is no fourth trochanter on the femur.	41. Femur has a well-developed fourth trochanter.
42. Internal trochanter is very feeble.	42. Internal trochanter is well developed.
43. Femur has no definite popliteal area.	43. Popliteal area is well defined on the femur.
44. Adductor ridge is long and high.	44. Adductor ridge is short and low.
45. Tibia is slender and long.	45. Tibia is stout and short.

[1] Except very rarely in very old individuals, where they form *almost* complete rings.

Of these items nos 3, 31, 32, 36, 42, 44, and 45 are correlated with the difference in size between the two genera, *Parioxys* being the smaller. However, the combination of features listed above [1] demonstrate clearly and beyond any doubt that *Parioxys* is a genus quite distinct from *Eryops*.

III. Relationship to the Family Eryopsidæ

Parioxys is not an eryopsid, a conclusion based on the above comparison with *Eryops*, the most typical of the Family Eryopsidæ, and confirmed by comparing the genus with *Actinodon* (Gaudry, 1887), *Onchiodon* (Romer, 1939, fig. 2), and *Sclerocephalus* (Branca, 1886).

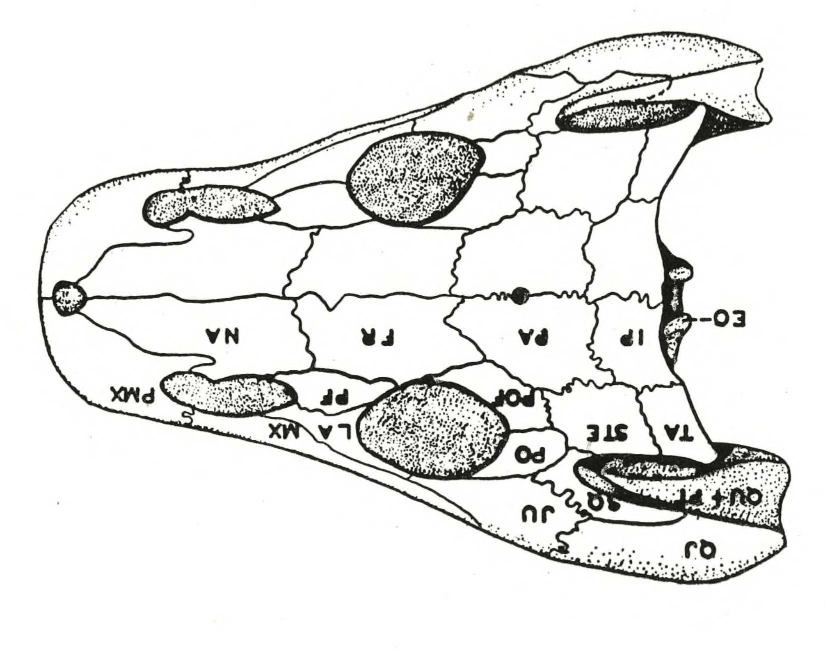
IV. Relationship to the Family Trematopsidæ

Neither is *Parioxys* to be included in the Family Trematopsidæ, as was suggested by Romer (1947, p. 167). It differs from the members of this family (*Trematops* and *Acheloma*—Olson, 1941) in the following :

1. The lack of the peculiar keyhole-shaped external nares.
2. The more posterior position of the orbits (see text fig. 2).
3. The exclusion of the frontal bones from the orbital borders by the pre- and post-frontals.
4. The failure of the lacrimals to extend backward to reach the orbits.
5. The larger development of the interpterygoid vacuities.
6. The narrowness of the parasphenoid.
7. The anteroposterior rather than the dorsoventral expansion of the iliac blade.
8. The absence of a fourth trochanter and a definite popliteal area from the femur.

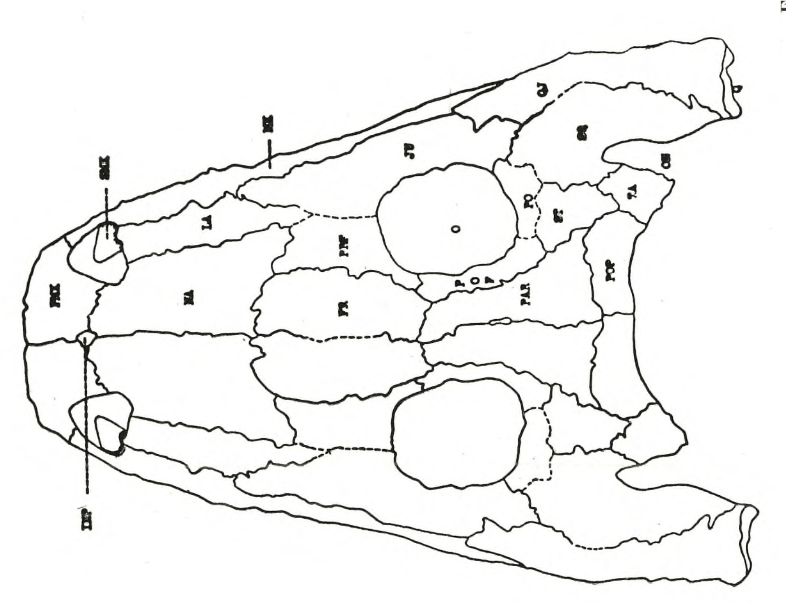
On the basis of skull characteristics alone, it might be argued that these differences are merely generic. However, the appendicular skeleton shows a number of differences of a very marked nature. In items nos 7

[1] Some of these differences are specific, some are generic, and others are on family level, as will be seen from the discussion on page 88 on.



Trematops willistoni. Skull in Dorsal View (After Olson).

Fig. 2



Parioxys ferricolus. Skull in Dorsal View.

and 8 the writer has noted only two clear-cut contrasts from among a whole series of differences, more fully discussed on pages 94-96.

However, apparently as a result of parallelism, there are certain structural features that are common to both *Parioxys* and the trematopsids, the most prominent of which is the development of ring-shaped intercentra in a part of the vertebral column of the former, and throughout its whole length in the latter [1].

V. Relationship to the Family Dissorophidæ

There exist a number of differences between the members of the Family Dissorophidæ and *Parioxys,* which make it inappropriate for that group to include this genus. These differences are [2].

1. The lack of dermal armor on the back of *Parioxys.*
2. The shortness of the dissorophid face compared to the postorbital region of the skull.
3. The formation of the dorsal portion of the dissorophid orbital margin by the frontals (*e. g., Broiliellus*—Williston, 1914; and *Tersomius*—Case, 1910, fig. 10).
4. The presence in *Parioxys* of ring-shaped intercentra in the posterior portion of the vertebral column.

However, there do exist certain resemblances between the appendicular skeletons of *Parioxys* and the dissorophids, the significance of which is fully discussed on page 95.

VI. Relationship to the Family Zatrachydidæ

So remote is *Parioxys* from the zatrachydids that it seems unnecessary to draw any comparison between them. It is worth mentioning, however,

[1] The vertebral column of *Acheloma* (as preserved) lacks such a feature, apparently as a result of the retardation of ossification which is related to the aquatic habits of this form (Olson, *op. cit.,* p. 159).

[2] The posterior closure of the otic notch is not included, since it is not present in all the dissorophids (*e. g., Broiliellus*—Williston, 1914).

that *Parioxys* is different from the members of the Family Zatrachydidæ in :

1. The small size of its internasal pit.
2. The lack of tabular horn development.
3. The absence of the peculiar shape of the quadratojugal of the zatrachydids, *e. g.*, *Zatrachys* (Broom, 1913, fig. 21), *Acanthostoma* (Steen, 1937), and *Dasyceps* (Huene, 1910).
4. The lack of lateral line canals, and better development of limbs, in connection with terrestrial living (Moustafa, in press).

VII. Systematic Position of *Parioxys*

Since it is not possible to include *Parioxys* in any of the hitherto-recognized four families grouped by Romer (1947) as the «Superfamily Eryopsoidea», the writer proposes to consider that *Parioxys* represents a separate new Family Parioxydæ, paralleling in time the «eryopsoids», and in many structural features the Family Dissorophidæ.

Family Parioxydæ, *fam. nov*

The characters given below clearly differentiate the Family Parioxydæ from the other families included in the «Superfamily Eryopsoidea», with which it agrees in the possession of double occipital condyles and an immovable basipterygoid articulation. Included in this family are terrestrial forms with slender limbs and a moderately elongated head. The skull is triangular with a moderately broad rounded muzzle, a median internasal pit, a moderately elevated table, and a slender lower jaw. The orbits are situated back of the mid-length of the skull roof. The lacrimals and frontals do not reach the orbital margins. The otic notches are enlarged. The marginal teeth are more-or-less uniform in size except for a group of three or five larger ones under the narial region. The internal nares are anteroposteriorly elongated. The interpterygoid vacuities are large, broad, and short, and are bordered anteriorly by the pterygoids. The intercentra may form complete rings in the posterior portion of the vertebral column. There are two sacral vertebrae. The processes for muscular attachment on the limb bones are feeble. The cleithrum is slender, narrow and sculptureless. The scapular blade is broad. The iliac blade is anteroposteriorly expanded and the pubis is well ossified. The femur lacks a fourth trochanter. The tarsalia are well ossified. There is no dermal armor.

A. Contents

Genus *Parioxys Cope* (Cope, 1878, p. 521)

Genotype : *Parioxys ferricolus,* Cope (1878, p. 521).
Original Description (Cope, 1878, p. 521).
Revised and Amended Description :

The median internasal pit is small and round. The external nares are situated quite close to the lateral margins of the skull. The pineal foramen lies a short distance in front of the posterior orbital borders. The tabulars are small and with but little exposure on the occipital surface. As seen from behind, the posterior border of the skull table is concave. The maxillae do not reach the level of the anterior borders of the otic notches. The parasphenoid has a pair of winglike structures on its ventral surface between the basipterygoid processes and occipital condyles (tubera parasphenoidales). The cultriform process of the parasphenoid is narrow. The palatine tusk pair is the largest of the palatal teeth. The angular is protruded outward and downward into a pronounced «angle» and there is only one meckelian fenestra (the posterior one), in the lower jaw. The anterior presacral vertebrae are rhachitomous in structure, while the sacrals and cuadals are «neorhachitomous». The pleurocentra may fuse with the intercentra. The anterior presacral ribs are double-headed, distally expanded in the dorsal region, and without uncinate processes, while the posterior presacrals are single-headed. The articular condyles of the humerus may be ossified. The humerus may have a separate but moderately developed supinator process. The puboischiadic plate is broad and slightly tilted medially. The acetabulum is formed by almost equal contributions from the three pelvic bones.

Included in this genus are two species : *P. ferricolus,* Cope, and *P. romeri, sp. nov.*

a. *Parioxys ferricolus,* Cope

(Synonym : *Eryops ferricolus,* Cope, 1884, p. 35)

Holotype : A. M. N. H. n° 4309 (Moustafa, 1952, p. 298).

Horizon and Locality : Belle Plains Formation (Wichita Group), near Mount Barry, ten miles west of Wichita Falls, Wichita Co., Texas, U. S. A.

Original descriptions (Cope, 1878, p. 521) :

Revised description (Case, 1911, pp. 32-33).

Amended description : The dermal skull roof is uniformly sculptured by small oval pits and low ridges. The muzzle is gently rounded in vertical cross section. Between the muzzle and cheek region there is a concavity at the anteroventral margin of the orbit. There is a faint ridge which runs along the nasal and frontal of either side. The septomaxilla is small, occupying the posterolateral corner of the triangular external naris. The internal naris is approximately four times as long as the external. The nasal is larger than the frontal. The parietal is triangular. There is a depression occupying the posterolateral portion of the nasal and the anteromedial corner of the prefrontal. The supratemporal does not reach the border of the otic notch. There are small denticles on the vomers, palatines, ectopterygoids, and pterygoids. The pterygoid is separated from the vomer and palatine by a pronounced rounded ridge. The precoronoid is undenticulate, the intercoronoid bears small teeth, while the coronoid is provided with very minute denticles. The prearticular extends far forward to reach the suture between the pre- and inter-coronoid. There is one pair of symphysial tusks (and probably two), housed in a triangular depression on the surface of the vomers. The glenoid is large. The humerus has neither a separate supinator process nor ossified articular condyles.

Due to the fact that *P. ferricolus* is the only well-known species, its description may overlap that of some other species of *Parioxys,* should these be discovered in the future. Should that happen, it will be necessary to transfer the characters common to all to the description of the genus *Parioxys.*

Referred Specimens :

M. C. Z. n° 1162 : Partial skeletons of at least eight individuals representing different growth stages; Belle Plains Formation, north of the Little Wichita River, southwest of Dundee, Archer Co., just west of the Wichita County line, Texas, U. S. A.

b. *Parioxys romeri, sp. nov.* (fig. 3).

Holotype : M. C. Z. n° 1965. Distal part of a left humerus.

Horizon and Locality : Belle Plains Formation, at Tit Mountain, two miles east and one mile north of Dundee, Archer Co., Texas, U. S. A.

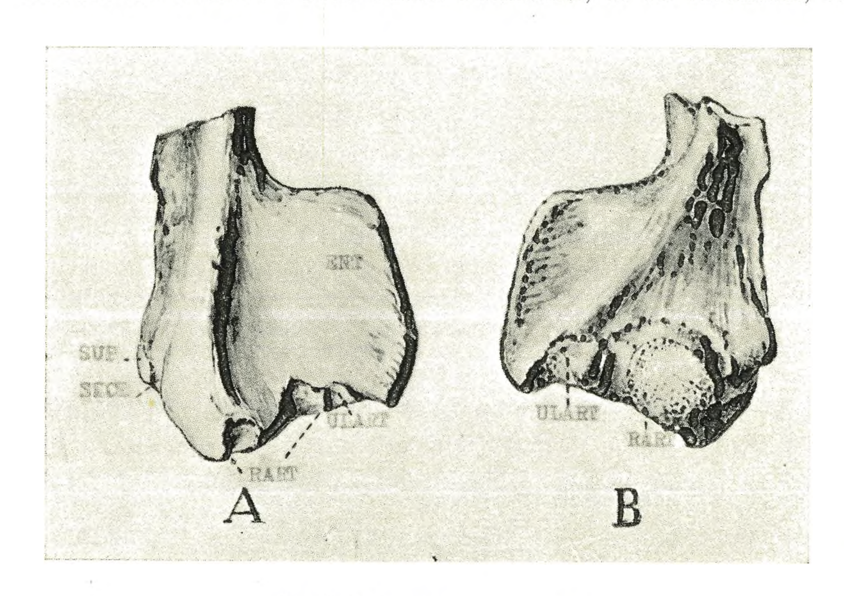


Fig. 3 *Parioxys romeri, sp. nov.*
Holotype, *M.C.Z.* n° 1965.
Distal part of the left humerus.

A. Distal dorsal surface. B. Distal ventral surface.

ECT ectepicondyle
ENT entepicondyle
GECT ectepicondylar groove.
RART radial articular surface
SUP supinator process.
ULART ulnar articular surface.

Description : The humerus has a distinct supinator process, bounded distally by a well-defined ectepicondylar groove. The articular condyles

for the radius and ulna are highly ossified. This species is much larger than *P. ferricolus*.

This new species is named in honor of Professor Alfred S. Romer of Harvard, distinguished student of amphibian and reptilian evolution.

B. Relationships of the Family Parioxydæ

The « Superfamily Eryopsoidea » and the four families included in it have been recently defined by Romer (1947, pp. 313-314). These definitions are based, almost exclusively, on skull structure, with very little consideration of the postcranial skeleton, particularly of the limbs and limb girdles. In the following table, the cranial as well as the postcranial structures (when the latter are available) characteristic of the three families Eryopsidæ, Trematopsidæ and Dissorophidæ [1] are compared with those of the Family Parioxydæ, in order to bring out the similarities and dissimilarities that may be of aid in the understanding of the possible relationships between them.

	Eryopsidæ	Trematopsidæ	Dissorophidæ	Parioxydæ
1. *Habit.*	Semiterrestrial.	Terrestrial or aquatic.	Terrestrial.	Terrestrial.
2. *Otic notches.*	Not greatly developed.	Greatly developed.	Greatly developed.	Moderately developed.
3. *External nares.*	Normal.	Elongate, including antorbital opening.	Normal.	Normal.
4. *Internal nares* [2].	Normal.	Normal.	Slightly elongate.	Excessively elongate.
5. *Frontals.*	Do not reach the orbital borders [1].	Reach the orbital borders.	Reach the orbital borders [2].	Do not reach the orbital borders.
6. *Lacrimals.*	Do not reach the orbital borders.	Reach the orbital borders.	Reach the orbital borders.	Do not reach. the orbital borders.
7. *Intercentra.*	Crescentic [3].	May form complete disks.	Crescentic.	May form complete disks.
8. *Sacral vertebrae.*	One.	One.	Two.	Two.
9. *Postglenoid region of coracoid.*	Small.	Small.	Large.	Large.
10. *Supinator process.*	Separate and strong.	Separate and strong.	Indistinct or feeble.	Indistinct or feeble.
11. *Deltopectoral ridge.*	Strong.	Strong.	Weak.	Weak.
12. *Humeral shaft.*	Short.	Short.	Long.	Long.
13. *Iliac blade expansion.*	Dorsoventral.	Dorsoventral.	Anteroposterior.	Anteroposterior.
14. *Fourth trochanter.*	Present.	Present.	Absent.	Absent.
15. *Popliteal area.*	Well defined.	Well defined.	Ill defined.	Ill defined.

[1] The Family Zatrachydidæ is excluded from this comparison for its at-once-apparent remoteness from the Parioxydæ, as well as the inadequate nature of our knowledge of its postcranial skeleton.

[2] The shape and size of the internal nares are considered with respect to those of the external.

This table reveals two important facts about the four families under consideration. In the first place, the structure of the axial skeleton (nos 2-8) demonstrates a case of multiparallelism not unusual or uncommon among fossil amphibians :

a. The Trematopsidæ and Parioxydæ possess ring-shaped intercentra.

[1] Except in *Osteophorus* (Meyer, 1860) which is known only from the impression of one skull, a situation which makes it uncertain whether the frontals did really reach the orbital borders or not.

[2] Except in *Platyrhinops* (Steen, 1931, figs. 11-13), in which they almost reach the orbits despite the fact that the latter are widely separated.

[3] Except perhaps in extremely old individuals (personal observation on *Eryops megacephalus*), when they form almost complete disks.

b. The internal nares are elongated in the Parioxydæ and Dissorophidæ.

c. The otic notches are highly enlarged and the lacrimals and frontals reach the orbital borders in the Dissorophidæ and Trematopsidæ.

In the second place, while such parallelism exists in the axial skeleton, the structure of the appendicular skeleton shows a clear-cut distinction between the Eryopsidæ and Trematopsidæ on one hand [1], and the Dissorophidæ and Parioxydæ on the other.

That this marked similarity in the postcranial structure of the Eryopsidæ and Trematopsidæ is an adaptive feature is very difficult to accept. *Eryops* is a terrestrial form (Sawin, 9141), while *Acheloma* is aquatic (Olson, 1941, p. 149); nevertheless, the similarities between their humeri, for example, are so great that Nilsson includes them in one type, the *Eryops* type (139, p. 30). A better and more logical explanation is that the Eryopsidæ and Trematopsidæ are related, a conclusion which also holds true for the Families Dissorophidæ and Parioxydæ.

VIII. The *Eryops* vs. *Cacops* Type of Appendicular Skeleton

In full agreement with Nilsson's view (1939, pp. 28-30) on the humerus of certain rhachitomes, it is the writer's conviction that the entire appendicular skeleton of the forms included in the Families Eryopsidæ, Trematopsidæ, Zatrachydidæ, Dissorophidæ and Parioxydæ falls into either an *Eryops* type (including the first three families) or a *Cacops*

[1] This conclusion contradicts Olson's statement that «the members of the family Trematopsidæ bear resemblances to the family Eryopsidæ and the family Dissorophidæ and appear to lie closer to the latter» (*op. cit.*, p. 173). However, as that author mentions on page 174, «the principal postcranial differences between the Eryopsidæ and Trematopsidæ are those of proportions, and a number of these may be related to the pronounced difference in size between the members of the two families».

type (including the last two). Despite the differences in size and adaptation among the individual genera included in one or the other type, the structures of their pectoral girdles, humeri, pelves, and femora consistently conform to the diagnosis of the type as given below.

1. The *Eryops* type [1].

a. Pertoral Girdle : The postglenoid region of the coracoid is small and dorsoventrally narrow, while the scapular blade is relatively high, *e. g.*, *Eryops, Actinodon, Onchiodon, Trematops*, and *Acheloma*.

b. Humerus : This element is short and broad, with all processes heavily developed. The two ends are at right angles. The shaft is short, the supinator process is very well developed, and the deltopectoral ridge is very prominent (Nilsson, 1939), *e. g.*, *Eryops, Actinodon, Trematops*, and *Acheloma*.

c. Pelvis : The iliac blade is dorsoventrally elongate. The acetabulum is placed closer to the anterior end of the puboischiadic plate, *e. g.*, *Eryops, Actinodon*, and *Trematops*.

d. Femur : The fourth trochanter is well developed and the adductor ridge bifurcates distally to enclose a definite popliteal area, *e. g.*, *Eryops, Trematops*, and *Acheloma*.

2. The *Cacops* type [2].

a. Pectoral Girdle : The postglenoid region of the coracoid is large and dorsoventrally broad. The scapular blade is relatively broad, *e. g.*, *Cacops, Dissorophus*, and *Parioxys*.

b. Humerus : This element is longer than broad, with a feeble development of processes for muscular attachment. The two ends are not quite at right angles to each other. The shaft is relatively long, the

[1] References to the examples : *Eryops* (Romer, 1922 ; Miner, 1925); *Actinodon* (Gaudry, 1883, 1887, 1888 ; Thevenin, 1910); *Onchiodon* (Credner, 1893); *Trematops* and *Acheloma* (Olson, 1941).

[2] References to the examples : *Cacops* (Williston, 1910 ; Case, 1911); *Dissorophus* (Williston, 1910 *a*; Case, *op. cit.*); *Parioxys* (Moustafa, 1950, and in press); *Alegeinosaurus* (Case, *op. cit.*); *Arkanserpeton* (Lane, 1932).

supinator process is very feeble or indistinct, and the deltopectoral ridge is weak, *e. g., Cacops, Dissorophus, Alegeinosaurus,* and *Parioxys.*

c. Pelvis : The iliac blade is anteroposteriorly expanded. The acetabulum is placed at about the mid-length of the puboischiadic plate, *e. g., Cacops* and *Parioxys.*

d. Femus : There is no fourth trochanter. The adductor ridge does not bifurcate distally and there is no definite popliteal area, *e. g., Cacops, Dissorophus, Arkanserpeton,* and *Parioxys.*

IX. Phylogeny of the « Eryopsoids »

In the light of the above-given analysis of the appendicular skeleton, the writer here proposes that the « Superfamily Eryopsoidea » of Romer should be split into two superfamilies. One, the Superfamily Eryopsoidea proper, is to include three families : the Eryopsidæ, Trematopsidæ, and tentatively, Zatrachydidæ. The other, a new Superfamily Dissorophoidea, is to include the two families Dissorophidæ and Parioxydæ. The two superfamilies and their contents may be defined as follows :

Superfamily Eryopsoidea :

Semiterrestrial or aquatic rhachitomous amphibians with a large head, immovable basipterygoid articulation, and tripartite or double condyle. The intertemporal is absent. The interpterygoid vacuities are of modest size, the pterygoids reach the vomers, and the quadrates are behind or on the level of the occipital condyles. There is one sacral rib. The ilium is dorsoventrally expanded and the femur has a well-developed fourth trochanter, a well-defined popliteal area, and a short, heavy adductor ridge. The humerus has a well-developed supinator process, a strong deltopectoral ridge, and pronouced processes for muscular attachments.

Family Eryopsidæ :

Semiterrestrial. The external nares are of normal build, the frontals do not reach the orbital borders, and there is no internasal pit. The otic notches are not greatly developed, and the quadrates lie behind the level of the occipital condyles. The vertebrae are typically rhachitomous throughout the column. *Eryops,* lower Permian of North America; *Actinodon, Onchiodon, Osteophorus, Chelydosaurus, Sclerocephalus,* lower Permian of Europe.

Family Trematopsidæ :

Terrestrial or aquatic. The external nares are long, including an antorbital fossa. The frontals and lacrimals reach the orbits and there is an internasal pit. The otic notches are greatly developed and the quadrates are either on the level of or behind the occipital condyles. The intercentra may or may not develop into ring-shaped structures. ?*Mordex,* upper Pennsylvanian of North America; *Trematops* and *Acheloma,* lower Permian of North America.

Family Zatrachydidæ [1] :

Aquatic or semiaquatic forms. Skull is depressed and broad. Muzzle is greatly expanded and usually with a fontanelle developed in the dermal bones. Quadrates are about on level of condyles. Limbs are weak. *Stegops,* upper Pennsylvanian of North America; *Zatrachys, Platyhystrix,* lower Permian of North America; *Acanthostoma, Dasyceps,* lower Permian of Europe (*fide* Romer, 1947, p. 314).

Superfamily Dissorophoidea :

Rhachitomes in which terrestrial adaptation has reached its peak. The head is of medium size and moderate height, the basipterygoid articulation is immovable, and the occipital condyle is double. The intertemporal is absent. The interpterygoid vacuities are enlarged, the pterygoids reach the vomers, and the quadrates are behind or on the level of the occipital condyles. The internal nares are slightly or highly elongated. There are two sacral ribs. The ilium is anteroposteriorly expanded. The femur lacks a fourth trochanter and a definite popliteal area. The adductor ridge is high and thin. The humerus has an indistinct, or at most feeble, supinator process. The deltopectoral ridge is weak, as are the other processes for muscular attachments.

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[1] The limb material is not sufficiently known to permit the expansion of the definition of this family to cover the postcranial skeleton.

FAMILY DISSOROPHIDÆ :

A dorsal dermal armor is well developed. The facial portion of the skull is short, and the orbits are usually placed close to each other at about the mid-length of the skull roof. The internal nares are slightly elongate. The frontals and lacrimals reach the orbital borders, and the quadrates are at about the level of the occipital condyles. The otic notches are highly enlarged. Throughout the vertebral column the intercentra are crescentic. The iliac blade is slightly anteroposteriorly expanded. The internal trochanter is moderately developed. The cleithrum is large. ? *Arkanserpeton*, ? *Platyrhinops*, upper Pennsylvanian of North America; *Cacops*, *Dissorophus*, *Broiliellus*, *Tersomius*, *Alegeinosaurus*, *Aspidosaurus*, lower Permian of North America; *Zygosaurus*, lower-middle Permian of Russia.

FAMILY PARIOXYDÆ :

There is no dorsal dermal armor. The facial portion of the skull is elongate, and the orbits lie in the posterior portion of the skull table. There is an internasal pit. The internal nares are excessively elongate. The frontals and lacrimals do not reach the orbits and the quadrates lie behind the level of the occipital condyles. The otic notches are slightly less developed than in the preceding family. The intercentra develop into complete rings of bone in the posterior portion of the vertebral column. The iliac blade is greatly expanded in an anteroposterior direction. The internal trochanter is weak. The cleithrum is small. *Parioxys*, lower Permian of North America.

It might be argued that the similarities in the postcranial skeleton of the dissorophids and parioxyds could be attributed to a similar terrestrial adaptation of forms of approximately the same size. However, such a fundamental character as the possession of two sacral vertebrae accompanied by the anteroposterior elongation of the iliac blade could not be accounted for on such grounds. A better terrestrial adaptation is a logical result of a better sacral support, rather than being its cause. It is therefore unlikely that this feature is the result of parallelism. It is more reasonable to assume that the similarities between the postcranial skeleton of the dissorophids and parioxyds are indicative of a common ancestry, a result of which is a similarity in adaptation.

Of the two superfamilies, the Eryopsoidea (*sensu stricto*) is the more primitive. This conclusion is based mainly on the nature of the system of the ventral ridges and trochanters on the femur. The presence of a ridge limiting the intertrochanteric fossa posteriorly is a primitive tetrapod characteristic (Romer and Price, 1940, p. 153). This structure is present in the eryopsoid families (the evidence is fragmentary for the Zatrachydidæ), while it is absent from the dissorophoids. Again, the presence of a fourth trochanter in the former is primitive, while its absence from the latter is a specialization. The specialized nature of the dissorophoids is further suggested by the absence of a definite popliteal area from the femur, the elongation of the internal nares, and the possession of two sacral vertebrae rather than the usual primitive univertebral sacrum.

Within the Superfamily Eryopsoidea, the Family Eryopsidæ is the most primitive, and is believed to have given rise to the Trematopsidæ and Zatrachydidæ. However, that *Eryops* itself is the ancestor of either or both families is very doubtful, since at least the Zatrachydidæ began their history in the late Westphalian [1] (*Stegops divaricata*—Romer 1930, pp. 114-118; Steen, 1931, pp. 860-865, figs. 8-10), while *Eryops* is not known before the Stephanian [2]. Moreover, *Eryops* is too large a form to be considered the ancestor of such smaller forms as *Trematops* or *Acheloma*. Should an *Eryops*-like form of smaller size and earlier occurrence than *Eryops* be found, it would be quite suitable for an ancestor to the Trematopsidæ and Zatrachydidæ.

Neither would *Eryops* furnish a suitable ancestor to the dissorophoids. It is too late in appearance to have given rise to the dissorophids, since, although the majority occur in the Clear Fork Group, *Arkanserpeton* is known from the Westphalian (Paris shale) of northwest Arkansas (Lane, 1932). Here again *Eryops* is much too large than the known dissorophids and parioxyds.

It is not improbable that the Superfamilies Eryopsoidea and Disso-

(1) Late Westphalian ≡ Zones C and D of the continental European floral series; Zones G-H-I of the English system (Westoll, 1944. pp. 8-9).

(2) The earliest positive occurrence of *Eryops* is in the Pueblo formation in Texas (Romer, 1935, table 1, p. 1625).

rophoidea evolved independently from a primitive rhachitomous stock such as the *Edops* group (Romer and Witter, 1942) *via* a micropholid stage of development. This is not difficult to accept, since such a fundamental feature as the loss of the intertemporal bone was independently acquired by the ichthyostegals as early as the upper Devonian. Other cranial structures common to the two superfamilies seem to be a mere reflection of the general trend common in the development of the different rhachitomous groups.

That the two superfamilies have a common ancestor is a reasonable assumption. Of the members of the *Edops* group, *Gaudrya* of the late Westphalian (Jaekel, 1911) seems to be the closest to the ancestry of the later Rhachitomi. It is small; the facial region of the skull is moderately elongate; and the lacrimals extend all the way between the orbits and external nares. Of its presumed descendants, the Eryopsidæ lies on the main line of evolution, while the Dissorophidæ is a side branch well adapted to terrestrial existence.

Within the Superfamily Dissorophoidea, the Family Dissorophidæ is the more primitive, and is likely to have given rise to the Family Parioxydæ. In the former, the lacrimals extend all the way between the external nares and orbits, the choanae are but slightly elongate, the intercentra remain crescentic structures throughout the whole vertebral column, and the iliac blade is but moderately expanded in an anteroposterior direction. In the Family Parioxydæ, on the other hand, the lacrimals are withdrawn from the orbital borders, the internal nares are highly elongate, the intercentra are ring-shaped structures in the sacral and caudal regions of the vertebral column, and the iliac blade is very well expanded in an anteroposterior direction.

The greater development of the dissorophid otic notches should not by any means be an objection to the proposed relationship between the two families, since it is quite likely that the early members of the Family Dissorophidæ, among which an ancestor to the Family Parioxydæ is to be sought, had moderately developed otic notches similar to those of *Parioxys*. It is reasonable to assume that such an ancestor lacked the dermal armor characteristic of the later dissorophids, an assumption necessitated by its absence from *Parioxys*.

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CANIS FAMILIARIS ÆGYPTICA

FROM PREDYNASTIC MAADI, EGYPT[1]

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The remarkably well-preserved remains of a carnivore were discovered in 1947 by Professor Moustafa Amer, Director of the Egyptian Antiquities Department, and Dr. Ibrahim Rizkana, of the Faculty of Arts, Cairo University, Egypt, while excavating what is now known as the Maadi Predynastic Cemetery at Maadi, a suburb of Cairo, Egypt (cf. Rizkana, 1952, p. 6). These remains, which were identified by the writer as those of the domesticated dog *Canis familiaris*, include :

1. An almost complete skull with the full complement of teeth on the left side. Of the teeth on the right side, only the three incisors, PM^1, half of PM^3, and M^1 are present.

2. The two rami of the mandible. On the right side all the teeth are *in situ*, with the exception of PM_1, PM_2, and M_3. All four premolars on the left side are missing.

3. Eight vertebrae : a slightly broken atlas, the axis, the third and fourth cervical vertebrae, and four of the anterior thoracic vertebrae.

4. The scapular blades of the two sides.

5. The left humerus.

On close examination the Maadi Cemetery domesticated dog proved to be identical with that of the Heliopolis Predynastic burial grounds (Moustafa, 1952). The skull of the Heliopolis individual, however, was in an extremely poor state of preservation. Therefore, additional information about the skull characteristics of the Egyptian Predynastic domesticated dog may be furnished by the Maadi Cemetery specimen. The dental formula is $\frac{3.1.4.2}{3.1.4.3}$, which is typical for *Canis*, the sagittal and lamb-

[1] Communication présentée en séance du 7 décembre 1953.

doid crests are rather weakly developed, the talonids of the lower molars are partly tranchant, and the tooth row shows all the characteristics of the domesticated dog *Canis familiaris*.

A remarkable feature in the mandible of this domesticated dog is its noticeable thickness and prominent convexity in the region of the first lower molar (fig. 1). This feature is reminiscent of the Pleistocene wolves, as, for example, *Canis latrans orcutti* (Schultz, 1938, p. 165) from the tar seeps of western North America. The retention of such



Fig. 1.—*Canis familiaris ægyptica.* Left mandibular ramus of the Maadi Predynastic Cemetery individual (1947) (× 0.9).

feature in the Predynastic domesticated dog of Egypt does not necessarily imply any direct relationship with such North American or any other wolf; it may simply amount to being a retained feature from the proposed ancestor of the domesticated dog, the wolf.

The Maadi Cemetery Predynastic dog was rather small in size, although it was a fully grown adult at the time of its death. It is even likely that the individual was rather old, as suggested by the full eruption of M_3 and the slightly worn condition of the talonids of the lower molars (fig. 1).

The partial remains of another domesticated dog were recently unearthed (1951-1952 season) by Professor Amer and Dr. Rizkana in a

burial ground one-half mile south of the Maadi Cemetery known as the Digla Predynastic Cemetery (cf. Rizkana, *op. cit.*, p. 6). The right ramus of the mandible with M_1 and M *in situ*, and the posterior half of the left mandibular ramus with PM_4, M_1, and M_2 in place are the only two fairly good skeletal elements which permit the recognition of the affinities of this animal. From what is known of its limb bones, it is possible to judge that the Digla Cemetery *Canis familiaris* was larger than that of the

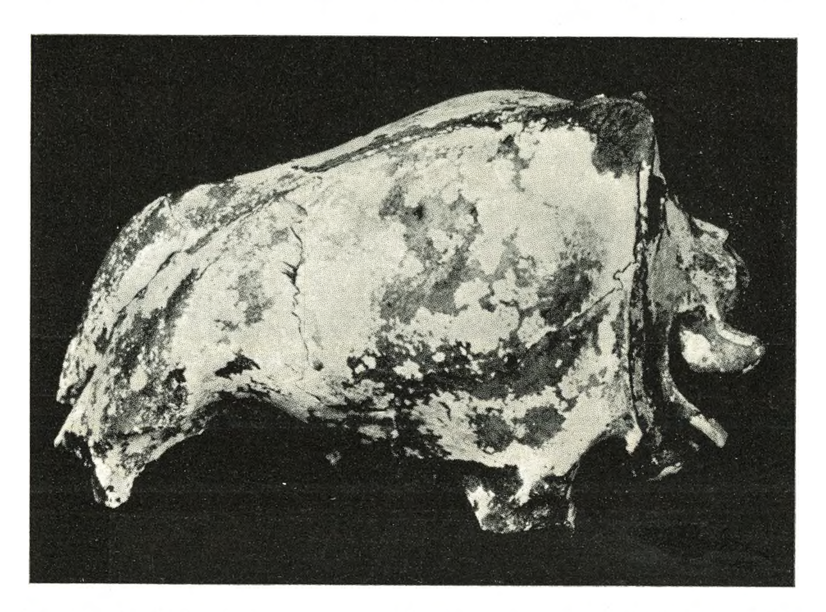


Fig. 2.—*Canis familiaris ægyptica.* Posterior portion of the skull of the Maadi Predynastic Settlement (1932) in lateral view (× 0.9).

Maadi Cemetery and about the same size as that found in the Heliopolis burial ground.

Professor Amer and Dr. Rizkana also kindly brought to the writer's attention the remarkably well-preserved cranial portion of the skull of an animal recovered from the Maadi Predynastic Settlement by Professor Amer in the 1932-1933 season (figs. 2-4). Although it has long been thought that of a beaver (no teeth being preserved), the cranium suggested itself at first sight to belong to the genus *Canis*; and upon comparison with the skull of the domesticated dog of the Maadi Cemetery, they were found to be identical in all respects. The settlement dog was most probably a

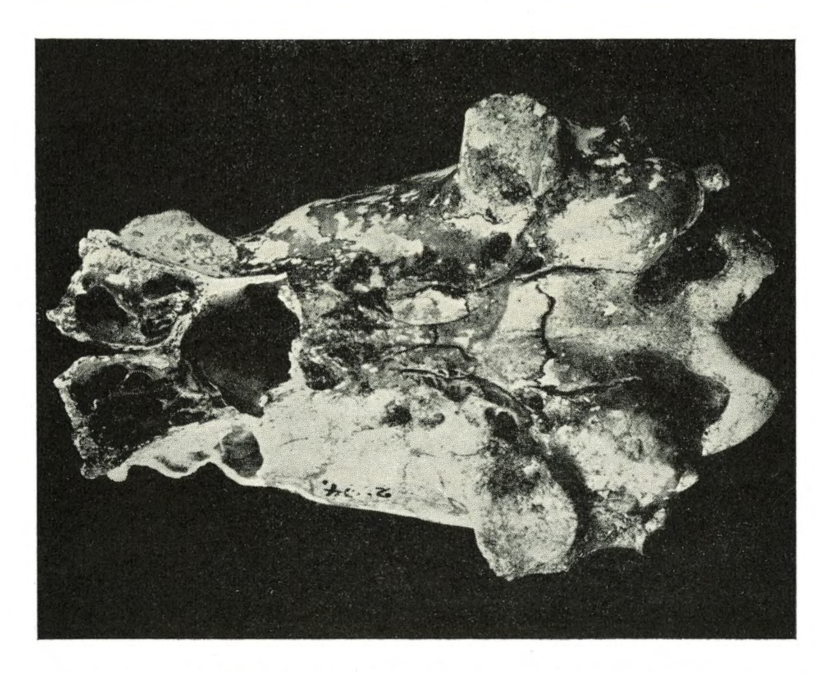


Fig. 3.—*Canis familiaris ægyptica.* Posterior portion of the skull of the Maadi Predynastic Settlement (1932) in palatal view (× 1).

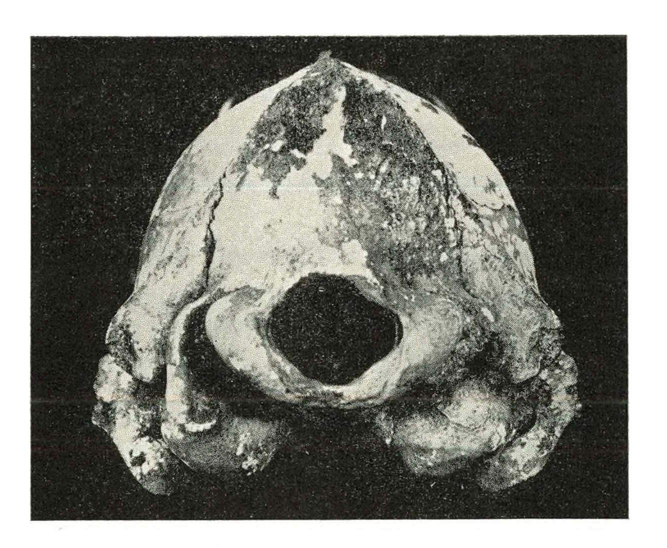


Fig. 4.—*Canis familiaris ægyptica.* The Predynastic Settlement skull in occipital view (× 1).

young individual, as suggested by the open suture between the basioccipital and basisphenoid, and that between the latter and presphenoid.

It is the writer's conviction that the domesticated dogs of the Maadi Predynastic Cemetery and Settlement deserve a subspecific distinction from the hitherto-known subspecies of *Canis familiaris.* The new subspecific designation *Canis familiaris ægyptica* is here proposed for the Maadi Predynastic dogs. The subspecific characteristics of *C. f. ægyptica* are the wolflike thickening and convexity of the mandible in the region of M_1, the weak development of the sagittal and lambdoid crests, the smallness of the supraoccipital processes of the frontal bones, and the relatively small size of the animal as a whole.

Although *C. f. ægyptica* is believed to have been fully domesticated, it is probably closer to the semiwild condition than any of the hitherto-known varieties of the early domesticated dogs. This belief is based on the retained wolflike character of the mandible, and is supported by the suggestion that the Maadi Predynastic Settlement belongs to a slightly earlier stage than that at Heliopolis (Rizkana, *op. cit.,* p. 7).

It has already been suggested (Moustafa, *op. cit.,* p. 104) that the Predynastic Egyptian probably worshipped the dog. It also seems likely that it was in connection with the function of the dog as a watch or guard that it occupied such a position in the theological life of the Predynastic Man. This is suggested by the fact that in each of the hitherto-known cemeteries, not more than one dog was discovered in each among the multitude of human and other animal remains. In each case the dog was buried in a grave of its own.

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Heliopolis, Egypt. June 17, 1953.

AN INTERPRETATION OF *ARSINOITHERIUM* [1]

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Introduction

In the fall of 1952 the writer volunteered to check and recatalogue the collection of fossil vertebrates in the Geological Museum in Cairo (referred to in this publication as G. M. C.). In view of the fact that this collection had not been adequately studied since the publication of C. W. Andrews's « Descriptive Catalogue » in 1906, it was necessary to review the material at the G. M. C. in the light of the mass of information which has accumulated in the past half century on comparative anatomy and vertebrate paleontology.

Arsinoitherium is admittedly the most striking of the Fayum faunule; yet, it is the least clearly understood (cf. Simpson, 1949, pp. 66-67). Andrews had devoted a considerable part of his monograph to the skeletal anatomy of this form; however, this author made a very sketchy interpretation of the creature as a once-living biological entity, and left the systematic position of the genus open to further investigation.

In this publication, it is the writer's intention to attempt an interpretation of *Arsinoitherium* as based on an understanding of its skeletal structure and an investigation of the musculature of the creature especially in connection with its feeding mechanism and its mode of living. A few additions to our knowledge of the skeletal anatomy of this animal are also made. The problematical systematic position and relationships of the genus are discussed in detail in a forthcoming publication.

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[1] Communication présentée en séance du 19 avril 1954.

I. Habitat of *Arsinoitherium*

In attempting to group the members of the Fayum vertebrate faunule, Andrews included *Arsinoitherium* in « the land-mammals which seem to be truly endemic to the Ethiopian region ». As a consequence, the genus has been accepted as a terrestrial form without any questioning to the correctness of Andrews's interpretation (1906, p. XII). However, certain peculiarities in the skeleton of *Arsinoitherium* suggest that this animal spent most of its life in a shallow water body close to the banks of a river or lake, wading about on the bottom, swimming occasionally, and resorted occasionally to dry land. This may well have been the case, providing *Arsinoitherium* with food, ease of locomotion, and protection from its carnivorous land-dwelling probable enemies. The proposed amphibious mode of living is suggested by :

1. The limb bones, girdles, and ribs are very massive structures in contrast with the sinuous nature of the skull and the light construction of the vertebral column, especially in the cervical and thoracic regions where the vertebral centra are strikingly short. It should be noted that, contrary to the impression of heaviness and massiveness it may leave at first sight (cf. Beadnell, 1902, pls. I-VI), the skull of *Arsinoitherium* is actually lightly built. Both frontal and nasal pairs of horns are hollow and their walls are thin, and there is an extensive sinus occupying the roof of the skull in the region of the nasal, frontal, and parietal bones, and may sometimes reach the base of the lateral prominences of the lambdoid crest (*e.g.*, G. M. C. n°s 9353 and 8256). The lower jaw is also lightly constructed ; the meckelian canal is wide, the bone of its walls is thin, and the expanded ascending ramus is equally thin. In contrast to the sinuous nature of the skull and light build of the mandible, the long limb bones of *Arsinoitherium* have a very narrow marrow cavity, almost no spongy bony tissue, and the periosteum is thick, dense, and ivory-like in structure (*e.g.*, G. M. C. n° 9378, an ulna).

2. The sacral attachment is extremely weak, as indicated by the fact that in no case was there any fusion of sacral vertebrae, and that in what Andrews considers the sacral vertebra of *Arsinoitherium zitteli* (*op. cit.*, p. 31, fig. 14), the iliac surface on the transverse processes is much too narrow as compared to the expansion of the iliac blade to accomplish the sacral support necessary for a successful land-dwelling form.

3. From the nature of the origin and insertion of the muscles of the anterior extremity, it is evident that *Arsinoitherium* was capable of adequately raising its humerus, while its ability to extend the upper arm was very much limited. This is suggested by the comparative strengths of the spinodeltoideus origin and insertion to those of the supraspinatus and infraspinatus muscles, the spinodeltoideus being much the stronger. The acromiodeltoideus too had a relatively feeble origin, suggesting a limited ability to flex the humerus, while the teres major, serving to lower the humerus, was but moderately developed. This adds up to the fact that the musculature of the front extremity of *Arsinoitherium* could not have permitted the animal to lead a successful terrestrial living. This extremity seems to have served as a prop for the huge weight of the animal, as suggested by the huge subscapularis muscle which served to keep the humerus close to the body.

4. As far as known, the limbs of *Arsinoitherium* are of the graviportal type characteristic of the relatively slow-moving Proboscidea (cf. Romer, 1941, p. 140), as well as the presumably amphibious dinosaurs *Brontosaurus* and its allies (Matthew, 1905). The humerus and femur of *Arsinoitherium* are relatively much too long compared with the lower segments of the fore and hind limbs respectively, a relation which results in an extremely short stride. The speed with which a relatively large form such as *Arsinoitherium* would have progressed on land seems to be ridiculously too slow to meet the competition with its contemporary lightly built terrestrial herbivores such as *Megalohyrax, Saghatherium Moeritherium, Phiomia, Palaeomastodon,* and *Ancodon,* or to avoid the probable attacks of its carnivorous contemporaries such as *Apterodon, Pterodon, Sinopa,* and probably *Hyaenodon.*

The problems of locomotion, protection, and procuring of food would be rather satisfactorily solved had *Arsinoitherium,* as proposed by the writer, lead an amphibious mode of living similar to that taken by the

hippopotamus and the huge sauropod dinosaurs. The buoying action of water would help keep the body afloat, while the massive limb bones and ribs would keep the lower part of the body immersed in water. This would enable the animal to wander about firmly and securely under water, with the feet touching the bottom, thus relieving the animal from supporting its huge bulk on a rather inadequately constructed limb apparatus. The water plants growing in the shallow depths of such water body as might have been the habitat of *Arsinoitherium,* and the foliage and twigs of the trees presumably growing in its vicinity would furnish the food of the animal (Moustafa and Shata, in progress). It may not at all be improbable that, in correlation with its large size, the stomach of *Arsinoitherium* was adapted for storing a considerable amount of food which would make it unnecessary for the animal to frequent dry land in search for food.

II. Tooth Character of *Arsinoitherium*

The greatest peculiarity of the teeth of *Arsinoitherium* lies, beside their unusual structure, in their hypsodonty at such an early time as the Eocene (cf. Andrews, *op. cit.*, p. XIII; Romer, 1945, p. 407). It has been repeatedly expressed that such hypsodonty was difficult to explain, especially because in the Eocene there were presumably no gramineous plants in the leaves of which abrasive material such as silica — responsible for excessive tooth wear—was deposited. It seems more likely that the development of a trend toward hypsodonty in the dental structure of *Arsinoitherium* is more directly related to the size of the animal more than to the kind of food which it consumed (cf. Romer, 1949, p. 14). The amount of food which an animal needs is admittedly proportionate to its volume (which changes proportionately to the cube of its linear dimension). A powerful dental apparatus is therefore necessary for the mastication of the comparatively huge amount of food which the animal needs. The jaws of *Arsinoitherium* are elongate, and the full complement of placental teeth is present, providing an area wide enough to affect a grinding capacity which is highly indispensable for the mastication of that amount of food. To offset the resulting amount of wear,

a continually growing battery of cheek teeth is a favorable acquisition for an animal as huge as *Arsinoithérium,* hence the observed trend toward hypsodonty.

However, despite their hypsodonty, the teeth of *Arsinoitherium* do not seem to have been efficient enough for a successful existence. This stems from the unequal distribution of enamel on the sides of the cheek teeth. On the lingual side of the molars and premolars the enamel covering ceases just beneath the cingulum, while on the labial side it extends down for a considerable distance toward the root. Consequently, the lingual side of the cheek teeth is covered only with cement at the advanced stages of wear. Naturally a cement-covered grinding organ is not as effective as an enamel-covered one; and from a functional point of view the cheek teeth of *Arsinoitherium* were not operating at an efficiency level comparable to that of the typical hypsodont teeth of the post-Eocene herbivorous mammals.

III. Jaw Muscles and Feeding Mechanism

The temporal muscle of *Arsinoitherium* was rather weak as indicated by the lack of a sagittal crest and the short expansion of the occipital crests. This muscle seems to have taken origin in two slips, the anterior from the supratemporal ridge (*str*—Andrews, *op. cit.*, pl. I), and the posterior from the occipital crest. The narrow character of the coronoid process of the mandible confirms the weak nature of the temporal muscle; however, this muscle seems to have been a little better developed than in the herbivores of later times, thus suggesting that *Arsinoitherium* was not, despite its unusual dental construction, too far removed from its pre-Eocene predecessors.

The masseter muscle was extremely well developed in *Arsinoitherium.* Beside the highly expanded labial surface of the ascending ramus of the mandible where the masseter was inserted (the coronoid fossa), there is a markedly strong stout ridge which runs along the posterior angle of the dentary, thus giving a maximum leverage for the jaw during the grinding of food. The relatively large size of the masseter indicates that the forward movement of the mandible during feeding was much more

important and essential to the feeding mechanism of *Arsinoitherium* than the orthal movement affected by the temporal.

The zygomatic arch where the medial slip of the masseter muscle presumably took origin is stout, particularly at its anterior end where the jugal is expanded along a vertical line. It is probable that a powerful infraorbital slip of the masseter was also present. The zygomatic arch, however, is rather short for a herbivore, and ends anteriorly right at the posterior end of the tooth row. Consequently, the masseter muscle seems to have acted not quite at right angles to the temporal, as might have been expected in a well-adapted herbivore. For this reason it is the writer's conviction that, contrary to the impression left by Andrews's treatment of the skeletal anatomy of *Arsinoitherium* in 1906, this form was not as well adapted for herbivorous living as is generally accepted.

The external and internal pterygoid muscles were very well developed as indicated by the expansion of the pterygoid bone and the presence of a stout rugose knob where the muscle presumably took origin. The inner surface of the ascending ramus of the mandible is markedly concave both from above downwards and from before backwards, providing a wide area for the insertion of the pterygoid muscles which acted to steady the mandible against the outward pull by the masseter and temporal muscles as well as to pull the jaw forward. The glenoid surface on the zygomatic arch is poorly delimited and much wider from side to side than from before beckwards, and the condyle is convex in all directions, thus permitting the mandible to move freely sideways during the mastication of food. This sideways motion was brought about by the action of the pterygoid muscles.

The jaw depressor, the digastric, had its origin, presumably, from the post-tympanic process of Andrews, which is probably the equivalent of the jugular process in other mammals. It is likely that the downward process from the exoccipital participated to a greater or lesser extent in giving origin to the digastric.

From the above reconstruction of the jaw musculature of *Arsinoitherium* the following may well be the animal's chewing mechanism. The temporal and masseter muscles combined affect the upward (orthal) movement of the lower jaw, while the masseter complex moves the mandible

in a forward direction. The pterygoid muscles move the jaw sideways, and in cooperation with the other muscles result in a kind of rotary movement of the lower jaw relative to the upper during the grinding of food.

The configuration of the glenoid surface favors the above interpretation, and a close examination of the manner in which the teeth wear confirms it. The surfaces of wear of the lower molars are tilted forwards, more so in the first molar than in the third, while those of the upper molars are tilted forward and inward. The surfaces produced by the action of the jaws past each other are more concave from side to side than from before backwards, thus conforming to the writer's interpretation of the type of motion the jaws went through during the grinding of food. The surfaces of wear of the premolars add to this argument. Those of the upper premolars are tilted inwards and backwards, while those of the lower premolars are tilted forwards and outwards, more so in the posterior than in the anterior ones. As a consequence of the inferred type of motion of the jaws of *Arsinoitherium*, the maximum amount of wear of the upper and lower teeth at any time in the life of an individual is exhibited by the anterior column of the second molar and both columns of the first molar, particularly the latter tooth.

IV. Prenasal Bar vs. *Os Internasalis*

It seems more appropriate, both from the descriptive and functional points of view, to designate the «prenasal bar» of Andrews (*op. cit.*, p. 2; fig. 2, p. 8—*mes*) as the *os internasalis* or internarial ossification, since Andrews's terminology may bear the implication that this bar of bone has a separate median center of ossification anterior to that of the paired nasals. The proposed change in terminology seems to be justified by that it is rather clear that this bar originated as a local ossification in the anterior portion of the cartilaginous internarial septum, taking place rather late in the life of the individual. The posterior surface of the *os internasalis* (or internarial ossification) carries a distinct cleft where the anterior end of the cartilaginous portion of the internarial septum was lodged.

It may well be true that this ossification is correlated with the relatively large size of the nasal horns in the adult *Arsinoitherium*, a condition which is paralleled in some rhinoceroses (Romer, 1945, p. 407), since the young had a completely cartilaginous septum and comparatively small horns (cf. Beadnell, 1902, pl. VI, bottom figure).

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THE FAYUM FOSSIL BONE FIELD [1]

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Introduction

Since the discovery of the fossil remains of vertebrates in the Fayum Province, Egypt, at the end of the nineteenth century (Schweinfurth, 1879), very little attention has been given to the details of the field occurrence of this fossil faunule. Even such meticulous investigator as H. J. L. Beadnell—whom we owe a great deal of our knowledge of the geography and basic geology of the Fayum Province—has made but a casual passing mention of the mode of occurrence of the fossil vertebrate remains in « The Topography and Geology of the Fayum Province of Egypt» (Beadnell, 1905). Such information is scattered in a few places of the text in the geological section of that work. For example, it is broadly stated that « The clays, marls, and limestones of the Ravine beds are frequently found to contain...... numerous small fish-scales, and occasional large teeth of sharks; while the skeletons of the toothed whole *Zeuglodon Isis* [2] are fairly common» (p. 39). The lithological association of the fossil vertebrates has hardly been touched upon at all, except in such places as footnote 2, p. 52, where a few examples are hastily listed. In his « Geologische Beobachtungen im Fajûm und am unteren Niltale in Ägypten», Dr. E. Stromer surveyed the situation in the Fayum without giving much attention to the field occurrence of the fossil vertebrates (Stromer, 1903).

[1] Communication présentée en séance du 19 avril 1954.

[2] *Zeuglodon isis* = *Prozeuglodon isis* (Stromer, 1908).

It is intended to present in this publication a short account of the field occurrence of the fossil veitebrates in the Fayum. Special attention is given to the nature of the major bone finds, the type of lithology they are associated with, and the factors which underlie each. In a detailed forthcoming publication (Moustafa and Shata, in progress), a list of all the species of vertebrates found at the different bone bearing horizons is presented, with the understanding that this list is purely stratigraphical, without any implication that at any single locality would all the listed species be collected. In the present publication, a paleogeographical reconstruction of the Fayum area during the Eocene is also presented; this reconstruction is necessarily approximate, emphasis being in the most part on the ecological aspects of the area in connection with its fauna.

I. Geographical Distribution of the Fossil Vertebrates (fig. 1)

The Fayum bone field lies to the north of Birket Quarun (pronounced Quaroon) between Gabal el Quatran to the north and the Quasr el Sagha —Gharet el-Îsh escarpment to the south. The major number of bone pits and « quarries» lies north-northwest of Gharet el-Îsh. However, a number of collecting localities is scattered to the east and west. The western limit of the bone-bearing area is a line connecting Naqb el-Garw (29° 35′ N, 30° 23′ E) with the western tip of the lake. To the southwest of this lies the « Zeuglodon Valley» from which profuse cetacean remains have been collected, hence the name. This valley is located east of Madwar el-Beghal and west-southwest to Gharet Ghonnam; in other words, it is 29° 15′ N, 39° 00′ E. The productive portion of the area is bound eastward by an ancient road connecting the Quasr el-Sagha Temple (29° 35′ N, 30° 41′ E) with Gabal el Quatran. This road was paved by the Ancient Egyptians for the workmen cutting the Gabal el-Quatran dolerites to worship at the Temple. The few prospecting pits which are located to the east of the old road are, so far, known to have yielded no fossil vertebrates at all. The island Geziret el-Quarn which occupies an approximately central position in the lake is also bone-bearing.

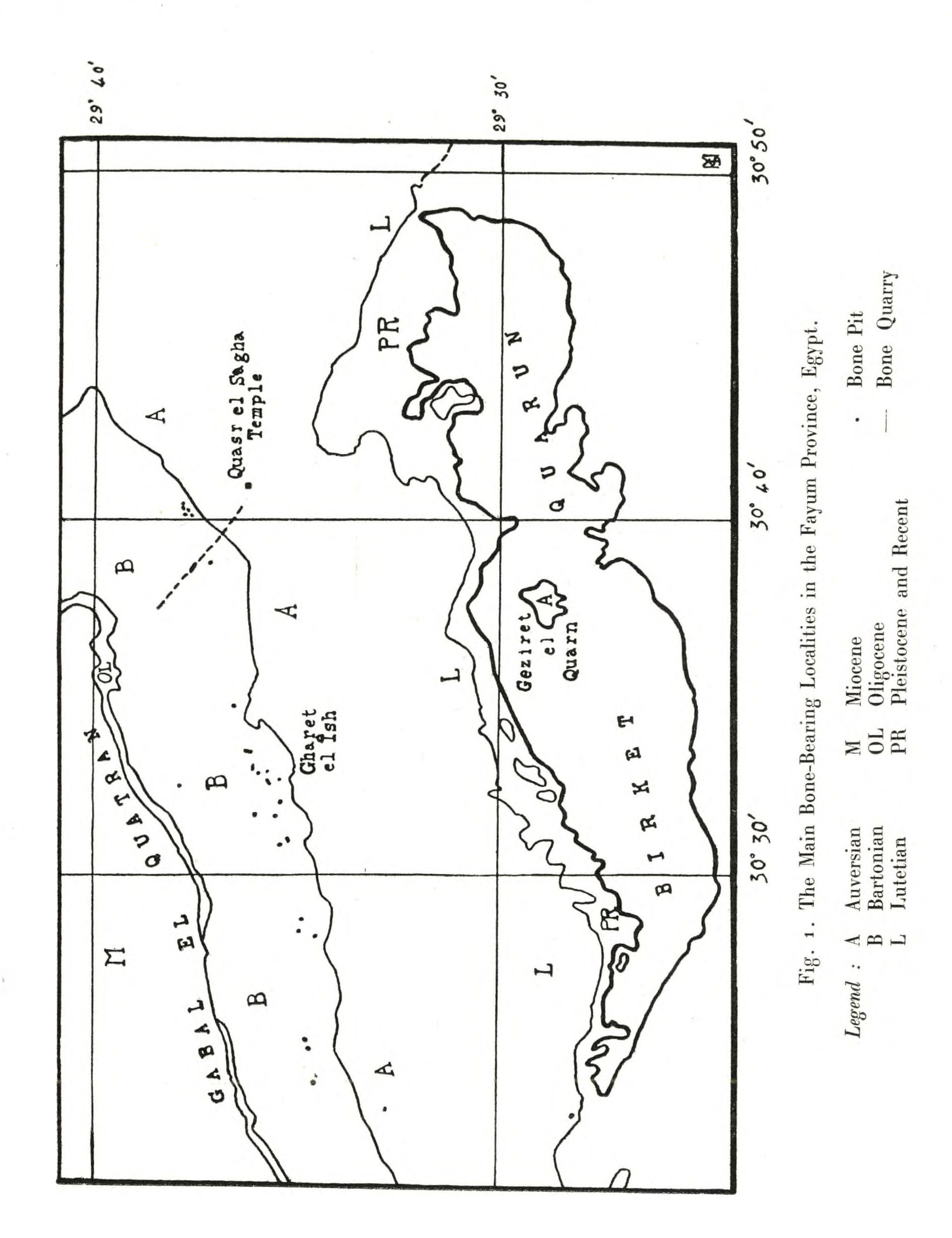


Fig. 1. The Main Bone-Bearing Localities in the Fayum Province, Egypt.

Legend : A Auversian M Miocene · Bone Pit
B Bartonian OL Oligocene — Bone Quarry
L Lutetian PR Pleistocene and Recent

II. General Character of the Fayum Bones

One of the most striking features is the extreme rarity of articulated and unmutilated skeletons among the multitude of vertebrate remains of the Fayum. Of over 1000 specimens in the Geological Museum in Cairo and American Museum of Natural History in New York[1], there seem to exist not more than a dozen instances in which a number of elements of the skeleton of one and the same individual were found in a natural state of association or articulation. The most important of these cases, rare as they are, as well as some others in other museums, merit to be listed.

1. About twenty articulated vertebrae of *Gigantophis garstini*, Andrews: G. M. C. n° 10022 (Andrews, 1901, fig. 1; 1906, pl. XXVI, fig. 1).
2. A complete thoracic, lumbar, and sacral series of *Moeritherium sp.*; G. M. C. n° 10005.
3. Three tarsal bones of *Arsinoitherium zitteli*, Beadnell, an instance which is quite unique among the remains of this species; G. M. C. n° 8403.
4. Skull and lower jaw of *Arsinoitherium zitteli*, Beadnell; B. M. N. H. (British Museum—Natural History, London) n° M-8463.
5. A nearly complete skull of *Prozeuglodon isis*, Andrews (= *Zeuglodon isis* = *Prozeuglodon artox*, Andrews—cf. Kellogg, 1936; Moustafa, in press), with the right ramus of the mandible in place; G. M. C. n° 9319[2].

[1] On a quick visit to the American Museum of Natural History (*A.M.N.H.*) in the Spring of 1950, the author surveyed the collection of Fayum fossil vertebrates in the Department of Geology and Paleontology. As of the Fall of 1952 he has been engaged in checking and recataloguing the fossil vertebrate collection at the Geological Museum in Cairo (*G.M.C.*).

[2] This specimen, together with a few others, has been loaned to the British Museum (*Natural History*) in London at the time of preparation of C. W. Andrews's *Descriptive Catalogue* published in 1906, and all have not yet been returned to Cairo (Personal communication with Professor M. I. Attia, Director of the Geological Survey of Egypt).

6. Six associated vertebrae of *Dorudon osiris*, Dames; G. M. C. n° 10051.
7. A good skull of *Fajumia schweinfurthi*, Stromer, with the anterior vertebral complex in position; B. M. N. H. n° P-10240.
8. Skull and articulated mandible of *Stereogenys cromeri*, Andrews; G. M. C. n° 10027.
9. The rostrum and aterior part of the mandible of *Tomistoma africanum*, Andrews; B. M. N. H. n° R-3201 (Andrews, 1906, fig. 86).
10. Twenty vertebrae of *Socnopaea grandis*, Stromer, in a natural state of articulation (Peyer, 1928, fig. 8).

The prevailing majority of the skeletal elements recovered from the Fayum bone field are found dissociated, and almost invariably broken to a lesser or a greater extent. The teeth of many of the terrestrial species of mammals, particularly those of *Phiomia* and *Palaeomastodon*, are usually found in a relatively poor state of preservation when found on the jaws of the animals to which they belonged. Of the latter genus, the skulls are almost always represented by the palatal elements alone or parts thereof. In innumerable cases, upper and lower jaws of many species of the Fayum faunule carry none but the alveoli of the teeth. Individual teeth rather than complete jaws or skulls are common (except for *Arsinoitherium*) over the greater part of the productive area.

The battered condition of the Fayum fossil bones, particularly those belonging to terrestrial forms such as *Moeritherium, Palaeomastodon, Phiomia, Ancodon, Geniohyus*, and *Apterodon*, indicate that such bones had been transported for some distance from where these animals lived and/or died. During transportation, the decaying away of ligaments would cause the disarticulation of the skeletons, and the impact of the transported elements upon each other would cause the breakage and damage characteristic of the Fayum bones.

The presence of a river to the west of the present course of the Nile flowing in a north-easterly direction and pouring its waters in the Eocene and Oligocene seas has long been suspected by a few workers on Egyptian geology (*e. g.*, Blankenhorn, 1902, pl. 10, fig. 1; Beadnell, 1905, fig. 6). The Eocene and Oligocene shore lines where this river

presumably poured its waters ran parallel to the general trend of the present day shore configuration of the Mediterranean Sea (fig. 2). This conclusion has been independently arrived at by the writer (Moustafa and Shata, in progress) and Dr. G. Knetsch, presently of the University of Cologne, West Germany, who in 1951-1953 inclusive, as Head of the Geology Department at the Faculty of Science, University of Cairo,

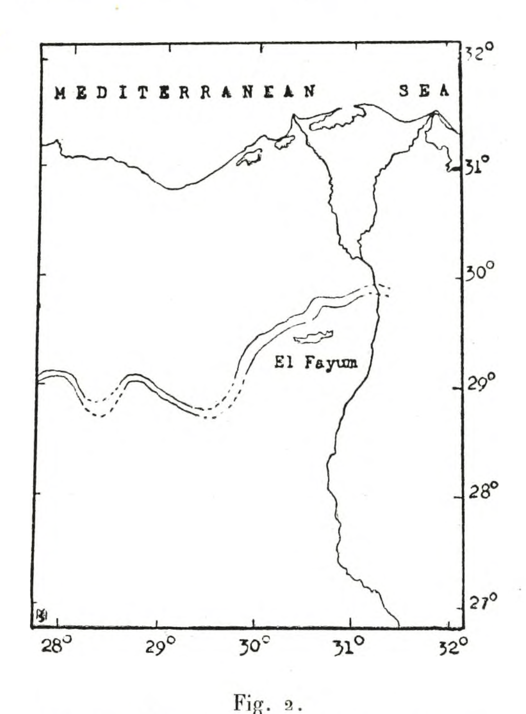


Fig. 2.
The Eocene Shore Line in the Fayum Region.

was engaged in the preparation of a tectonic map of Egypt. It is this river that may have brought the dead remains of inland terrestrial forms beside those of a typically marine faunal assemblage such as the different archaeocetes and sirenians. The fact that the epiphyses of the limb bones and the ends of the vertebral centra are frequently missing or found detached indicates a period of prolonged soaking in water with also seems to have caused the eating away of the ends of many long bones.

The proposed presence of a fresh water lake in the area occupied at the present time by the Baharia Oasis conforms with the palaeobiological

picture which seems to have existed to the west of the present course of the Nile during the Eocene. The Fayum faunule is predominently herbivorous, *e.g.*, *Arsinoitherium*, *Moeritherium*, *Palaeomastodon*, *Phiomia*, and the different hyracoids, and the profuse vegetation necessary for its feeding could have very likely grown in the vicinity of such fresh water lake. Moreover, the lake itself is a logical habitat where *Arsinoitherium* could have lead a reasonably successful life, since it is the writer's conviction that this archaic creature lead an amphibious rather than a terrestrial mode of living (Moustafa, in press). One may further speculate that the terrestrial faunal assemblage which found its final resting place in the Fayum shore line was inherent to the land mass in the vicinity of the Baharia Oasis from which it was transported, post-mortem, by the waters of the river.

III. Lithological Association of the Fayum Fossils

The greater majority of the Fayum fossil vertebrates occur in sands, sandy clays, clays, and marls. This is true for the remains of fishes, reptiles, birds, terrestrial, amphibious, and marine mammals. The above statement holds true for the three stratigraphically lower bone-bearing series : the Ravine, Birket Quarun, and Quasr el-Sagha beds. Only rarely are the fossils found in sandstones, as for example, the remains of archaeocetes in the « Zeuglodon Valley ». Occasionally, the remains of marine forms, such as the Archaeoceti and Sirenia, may be located in limestones. Excellent natural endocranial casts are sometimes found, notably those of *Dorudon osiris*, Dames (Stroemer, 1908, pl. V, figs. 12-13), *Dorudon elliotsmithii*, Dart (Smith, 1903, fig. 1), and *Dorudon sensitivus*, Dart (Dart, 1923, figs. 1-4). The exceptionally remarkable cast of the nasal and frontal sinuses of *Dorudon zitteli*, Stromer (Stromer, 1903 *a*, pl. X, fig. 2 ; pl. XI, figs. 1-3) has been recovered from sandstone.

The dissociated and fragmented skeletons occur over a wide area in the bone field. However, individual specimens are sometimes met with, and these are usually in a fine state of preservation (*e.g.*, the type of *Arsinoitherium zitteli*, Beadnell—1902, pl. VI ; G. M. C. n° 8130).

More often, bones are found in moderate numbers at the base of lens-shaped pockets in marls and clay beds. Some sandy pits may yield remarkably undistorted specimens (*e.g.*, the facial portion of the skull of *Prozeuglodon isis,* Andrews—Moustafa, in press). An unusual field occurrence is the presence of a very large number of dissociated skeletal elements, sometimes reaching over a few hundreds, in bone « quarries», a term developed by the American Museum of Natural History's Expedition to the Fayum in 1907. Torrential currents seem to be responsible for the bringing together of this large number of bones.

The best preserved and least distorted specimens come from sand pits or marls; bones coming from clays are usually very badly crushed, while those recovered from sandstones are usually in a fair condition. In some cases the sandstones encrust the bones in such a manner that renders the specimens of practically no value.

In prospecting for fossil vertebrates in the Fayum, the surface pebbles play a most unhelpful role in obscurring the outcropping parts of the fossils. This, together with the fact that the newly exposed bones are readily acted upon by weathering, makes prospecting rather tedious, and sometimes discouraging. However, the collector is usually gratified once he has located a bone find by the readiness of developing the fossils, particularly those embedded in sands.

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PETROGRAPHY OF THE ALKALINE VOLCANIC ROCKS OF YAMAN

EGYPTIAN UNIVERSITY SCIENTIFIC EXPEDITION TO S. W. ARABIA[1]

BY

N. M. SHUKRI AND E. Z. BASTA

I. Introduction

During the period April to October of 1936, the first author took part in the Egyptian (now Cairo) University Expedition to the south-western portion of Arabia, namely Yaman, el-Makalla, Hadramout and 'Aden Protectorate (Huzayyin 1936 and 1937). The route of the expedition in Yaman is given in fig. 1. Starting with 'Aden the route followed Lahdj then Ta'iz and from there the region of Hudjariah in the south of Yaman was examined; then from Ta'iz the route passed westward to Makha in the coastal plane of Tihama and northward through Heis, Zabeed, and Beit al-Faqeeh to Hodeidah on the coast. From Hodeidah the Tihama plane was crossed eastward over to San'aa on the high plateau, passing by Badjil, Madinat al-'Abeed and Ma'abar. From San'aa an excursion to Dj. al-Nabi Shu'eib and two others to the North of Yaman were made : one to Wady Kharid, Na'it and Reidah, and the other to 'Amran, Kuhlan, Haddjah and Wadi Sharis areas. The

[1] Communication présentée en séance du 3 mai 1954.

expedition then returned from San'aa to Hodeidah by the old mules-road passing through Mafhag, Manakha, Hadjeilah, 'Ubal and Badjil. From Hodeidah a boat was taken to Perim Island, 'Aden and el-Makalla.

The low lying coastal plane (Tihama), the high volcanic plateau formed of bedded lavas and pyroclastics, parts of its western and southern edges where basement rocks and Jurassic sediments appear due to rifting, and the north east part of Yaman where the Jurassic reappears and Pleistocene volcanoes are common, were examined. The basement rocks which outcrop in the south in Lahdj and Hudjariah at Turbah, and at the western margin of the plateau are overlain in the north-west (Wady Sharis) by pre-Jurassic (probably Carboniferous) and Jurassic sediments (Lamare 1930 C). The Jurassic is marine and is of Sequanian-Kimmeridgian age (Basse 1930). It is divided into a lower shaley series and an upper limestone series and these in turn are overlain by a sandstone series of the Nubian facies (of supposed Cretaceous age). The Nubian sandstone is cut by different sills and dykes (alkaline syenite-porphyries, bostonites, dolerites, olivine dolerites and ankaramites) that probably formed passages for the superfacial volcanics (pl. I, fig. 2 and pl. II, figs. 3-4). In the south, however, the Jurassic sediments disappear and the Nubian series overlies directly the peneplaned surface of the basement rocks (pl. III, fig. 5).

To the east and north of the basement rocks, the Plateau of Yaman is formed of a huge series of bedded plateau lavas and pyroclastics, probably of Upper Cretaceous or Lower Tertiary, which overlie directly the Nubian Series (pl. IV, figs. 7-8). To the east and north of San'aa the Nubian and Jurassic sediments (pl. I, fig. 1) reappear and the Trapp series dies away. In the neighbourhood of San'aa, in Belad Hamdan ('Amran, etc.) and at Perim Island a more restricted volcanicity of a more recent age than the bedded plateau series was also examined. These rocks are most probably of Pleistocene age and they follow the main present topographic features, overlying old gravels but are themselves affected by a more recent pluvial period (pl. V, figs. 9-10). A younger volcanicity is also present as the flows were not affected by subsequent erosion like the Pleistocene lavas (pl. VI, figs. 11-12). A sketchy geo-

logical map of the country is given by Wissmann (1932) and by Lamare (1936).

Lamare gives a summary of the previous works on the volcanic rocks of Yaman and 'Aden up to the year 1936 (*op. cit.*). The examination by Roman (1926) of the collection of Botez (1912) collected from Yaman along the Hodeidah-San'aa road, during his hydrological studies, seems to be the most detailed examination available at present of the volcanics of Yaman. Roman described the following types, all of which are supposed to be of the plateau volcanics : comendites and their tuffs, trachytes and their tuffs, «plagitrachytes» and their tuffs, hololeuco-trachyandesites, trachyandesites, hololeuco-trachydolerites, and trachydolerites. Lamare (1930 A and B) produced a geological map of the neighbourhood of San'aa and gave a concise description of the volcanics of Yaman both of the older bedded type and of the more recent central type. He seems to be the first to give a description of the Pleistocene volcanics of the mainland and noticed that the identification of some of the rocks described by Roman is inadequate (1930 A). Lamare records the following types of the plateau series : rhyolites and tuffs, rhyolites with lithophysae, comendites and tuffs, basalts with porphyritic felspar approaching either andesites or ankaramites, basalts with porphyritic augite and olivine, and nonporphyritic basalts. He records olivine basalt from the Pleistocene central type. Rathjens and Wissmann (1934) described the field occurrence of some of the more recent volcanics during their geographic studies of Yaman.

The present investigation deals with the pretographical and chemical composition of the plateau lavas and of the Pleistocene volcanics collected during the 1936 expedition. The pyroclastic rocks of Yaman and the volcanics of 'Aden will be dealt with in two separate works.

In the field, the bedded Trapp series is widely distributed and the tuffs accordingly were probably deposited under water. The rifting that gave rise to the Red Sea is very well displayed at many places especially at the landward border of the Tihama coastal plane. During the last war, Wissmann, Rathjens and Kossmat (1942) discussed the structure of Arabia including Yaman and Bab el-Mandab.

II. Field Occurrence

a. *The Tertiary Volcanic Rocks*

The high volcanic plateau of Yaman is formed of stratified Trapp series overlying the Nubian sandstone (pl. IV, figs. 7-8), and is probably of Upper Cretaceous or Lower Tertiary age. This series is very regular, generally of a constant thickness, and is formed of rhyolites, trachytes, trachyandesites and basalts, together with their corresponding pyroclastics. It shows no visible craters but are formed by fissure eruptions. In the following lines the succession of these volcanics at certain localities are given :

I. *Section at Ta'iz, south-east of el-Qahera.*— It is formed of rhyolites and rhyolitic tuffs. The succession is : Top-Columnar lava (5252-5256) [1] dipping NNW formed of pinkish-brown rhyolite with microcrystalline to cryptocrystalline groundmass.
Reddish coarse rhyolitic tuff (5251).
Greenish bed (5250) of rhyolite with microcrystalline to cryptocrystalline groundmass.
Coarse rhyolitic tuffs, greenish (5248) or pinkish (5247).
Banded rhyolitic obsidian (5246).
Greyish-white rhyolite with microcrystalline to cryptocrystalline groundmass (5245).
Base of formation (5244) formed of very fine black tuff.

II. *Section at el-Qa'ada.*— About 20 miles N. E. of Ta'iz. The succession is as follows :
Top-Grey comendite tuff (5314).
Rhyolitic obsidian (5315) and rhyolites showing lithophysae.
Rhyolitic obsidian, greenish in colour (5317).
Amygdaloidal nonporphyritic basalt (5318).

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[1] Numbers refer te samples housed in the Geology Department, Faculty of Science, Giza.

Porphyritic olivine basalt greenish on the surface (5319).
Coarse trachytic tuff (5320) at the base.
The whole series dips N. E.

III. *Section at Djebel Bihan.*— Two miles W. of el-Turbah. The succession is formed of trapp series intercalated with Nubian sandstone.
Top-Basalt about 15 m. thick (5446).
Nubian sandstone 5-7 m. thick.
Basalt 5-6 m. thick (5442).
Sandstone more than 35 m. thick.

IV. *Section at Djebel Mogash.*- About 4.3 kms. SW of San'aa. The succession showed :
Top-Columnar basalt 1.5 m. thick (5531).
Fine pinkish rhyolitic tuff, 5 m. thick (5530).
Conglomerate, dark in colour about 2 m. thick (5528).
Coarse rhyolitic tuff, about 10 m. thick (5524).
Basalt 2 m. thick forming the base of the bedded volcanic series (5523).

b. *The Pleistocene Volcanic Rocks*

These rocks belong to the normal central type of eruption. They form basaltic cones (pl. VI, figs. 11-12) which are usually localised in the vallies at different places in the north of Yaman, *e.g.*, Kaulet el-'Erg, Kaulet el-'Erra, and Kaulet Kodam (in Hamdan to the N. W. of San'aa) or in Wady el-Kharid and Wady Baten where they overlie the Jurassic limestone (pl.V, figs.9-10). Some volcanic bombs are found at the top of the cone, *e.g.*, at Kaulet el-'Erg and have a diameter ranging from 20 to 25 cms.

It is very likely that the volcanic eruptions which gave rise to these Pleistocene lavas have taken place during a dry phase which separated two rainy periods (Huzayyin 1936 and 1937). This is obviously seen in pl. V, figs. 9-10, where two Pleistocene basalt outcrops occur on both sides of Wady el-Kharid with Jurassic limestone on either side. A younger volcanicity is also present as some flows were not affected by the subsequent erosion (pl. VI, figs. 11-12).

Lamare (1930 B) distinguished two divisions :

1. « Subrecent series » formed of basalts usually doleritic of crater-type which overlie trapp series, Nubian sandstone or Jurassic limestone.

2. « Very recent series » which is younger and covers the alluvium of the vallies.

III. Petrography

a. *The Tertiary Volcanic Rocks*

The Plateau volcanic rocks of Yaman vary from the acid rhyolites and comendites to the basic basalts and ankaramites. They form an alkaline series, which could be compared with the volcanics of the neighbouring rift vallies. In the present section the petrography of the different rock types is briefly described. It embodies the results of the examination of some 1000 thin sections and some 20 new chemical analyses.

I. Rhyolites.

The acid rocks of Yaman are alkaline and are divided into two groups :

1) Those containing alkaline metasilicates (comendites and pantellerites), and 2 those devoid of such minerals.

1) Comendites : Both Roman (1926, p. 317) and Lamare (1930 A) described « comendites » in Yaman. Roman, however, did not describe any alkaline metasilicates in his « comendites ». In the present work three types of different texture and composition are described :

a. *Spherulitic riebeckite comendite.* — This type occurs in Ta'iz and is formed of clear soda-sanidine ($2V = -45°$) phenocrysts (0.6-2.3 mm.) in a microspherulitic groundmass containing much riebeckite and quartz. The microspherulites (0.3-0.5 mm.) are usually spherical, and consist of radiating intergrowths of felspar and quartz needles, occasionally showing micrographic intergrowths. Some spherulites have a nucleus of either quartz or riebeckite whereas others have a quartz core, followed outward by a zone of radiating riebeckite then by the normal intergrowths

of quartz and feldspar (pl. VII, figs. 13-14). Microspherulites consisting completely of radiating riebeckite are also present. A quantitative mineral analysis [1] gave the following approximate results :

Quartz 36.5 %, Soda-sanidine 50.5 % and riebeckite 13 %.

A chemical analysis of the rock is given in Table I, column 1. It compares fairly well with a comendite from Sardinia (Table I, column 3) described by Prior (1903, p. 258). The calcium content, however, is conspicuously greater than in the original comendite and the average given by Daly (Table I, column 4). Roman (1926, p. 244) described a chemically similar rock (Table I, column 2) from San'aa as a soda trachyte.

b. *Cryptocrystalline aegyrine rhyolite (comendite).* — This type occurs at el-Barh (between Ta'iz and Makha). It consists of phenocrysts of quartz and soda-sanidine in a cryptocrystalline groundmass containing numerous microcrystals of aegyrine (5421). The quartz is usually corroded and embayed and the groundmass shows flow structure and imperfect microspherulites. A chemical analysis of the rock gave 77.24 % SiO_2, 4.14 % Na_2O and 3.77 % K_2O and is clearly related chemically to comendite. Lamare described a comendite (1930 A, p. 77) which is related to the present type.

c. *Aegyrine-katophorite « pantellerite ».* — This type occurs between Manakha and Wessil (5885-5891), between Wessil and Hadjellah (5900), between Hadjellah and 'Ubal (5967) and N. W. of Safan (5968).

It is formed of phenocrysts (3.50 - 1.85 mm.) of anorthoclase in a microcrystalline groundmass of quartz and felspar containing abundant aegyrine needles. These aegyrine needles form about 50 % of the groundmass and are arranged subparallel in the direction of flow. Aegyrine (about 0.4 mm. × 0.01 mm.) is strongly pleochroic X = clear green Y = yellowish-green and Z = brownish-yellow. A few katophorite idiomorphic crystals of about 0.32 mm. are present. It has a $Z \wedge c = 42°$ and is pleochroic with X = yellowish-brown, Y = reddish-brown and Z =

[1] Quantitative determination of the mode was carried out by means of a Leitz integrating stage.

greenish-yellow. No chemical analysis is available for this type but it resembles the crystalline aegyrine pantellerites (Santelmo type) described by Washington (1913, p. 699) from Pantellaria except that its groundmass is coarser.

A related rock is a boulder of grorudite (5470) from Hais, Under the microscope (pl. VIII, figs. 15-16) it is very similar both in structure and mineralogy to the Christiana grorudites.

2) Rhyolites devoid of soda metasilicates : Although these are devoid of soda metasilicates yet they are alkaline in nature. They are usually hololeucocratic except for the presence of some magnetite and haematite. Roman (1926, pp. 232-237) described « comendites » that are devoid of alkaline metasilicates and are accordingly considered here. Lamare (1930 A, p. 77) described a rhyolite with lithophysae and spherulitic aggregates and a vitreous rhyolitoid [1].

The rhyolites are widely spread and abundant in the plateau volcanics of Yaman and show great differences in structure. The following types are recorded in the present work :

a. *Spherulitic or granophyric rhyolite.* — This is specially present at Ta'iz. In hand-specimen it shows sometimes flow structure or banding (5278) and occasionally spherulites some 2 mm. in diameter (5277). It consists of phenocrysts of clear soda-sanidine or soda-orthoclase and much corroded quartz in a crypto- to microcrystalline groundmass of quartz and felspar often intimately interwoven in spherulitic, micrographic, branching and interpenetrating forms. The spherulites may form up to some 80 % of the groundmass (5230). They are rounded, oval and are either isolated or are coalesced together to form elongated bands, or are closely packed together so as to constitute the bulk of the groundmass. Sometimes the groundmass shows typical micropegmatitic structure (5231). This consists of micrographic intergrowth of quartz and orthoclase showing myrmekite-like intergrowth or the constituent minerals of the intergrowth may be acicular, feathery or irregular. The groundmass sometimes shows a micropoecilitic structure (5231), minute

[1] A term used by Lacroix (1923, p. 2) to mean rhyolite without modal quartz.

felspar crystals with no orderly arrangement are enclosed in small areas of quartz. Such a structure differs essentially from the micrographic in that it indicates successive rather than simultaneous crystallization of the two constituent minerals.

Two chemical analyses of an example from Ta'iz (5231) are given in Table II, columns 1 and 2. A quantitative mineralogical analysis of the same rock gave the following results :

35.9 % quartz, 61.7 % soda-sandinine and 2.3 % magnetite and haematite. Though the rock does not contain any alkaline metasilicates yet the chemical analysis shows that it has an alkaline affinity.

It compares fairly well, both in chemical and mineralogical composition, with the group of alkaline leucocratic rhyolites given by Johannsen (1932, vol. II, p. 61). The alumina content of the analysed specimen is lower than the average analysis of rhyolites given by Daly (Table II, column 6).

Table I

	1	2	3	4
SiO_2	73.42	71.69	74.76	73.51
Al_2O_3	10.49	10.75	11.60	11.43
Fe_2O_3	1.72	4.44	3.50	2.97
FeO	0.97	0.44	0.19	1.08
MgO	—	0.53	0.18	0.16
CaO	2.22	2.57	0.07	0.28
Na_2O	4.56	4.46	4.35	4.65
K_2O	4.20	4.19	4.92	4.53
H_2O	1.88	0.88	0.64	1.02
CO_2	0.70	—	—	—
TiO_2	—	—	—	0.29
P_2O_5	0.27	—	—	0.04
MnO	0.05	0.86	—	0.04
Total	100.48	100.81	100.21	100.00

1. Comendite, I (II). (3) 4.1.3''. Ta'iz (5202). Analyst : Chem. Dept. Lab., Cairo.
2. Comendite. ''II.4.1.3. San'aa (soda trachyte of Roman, 1926, p. 244). Analyst : I. Copuzeanu.
3. Comendite. I''. ''4.1.3. Comend, Sardinia (Prior 1903, p. 258). Analyst : G. T. Prior.
4. Comendite, average composition of Daly (1933).

On the other hand, the potash content is higher than the average. In the norm acmite is present but in the mode the alkaline character is restricted to the presence of soda felspars. Related rocks are described by Roman (1926, p. 236) and by Lamare (1930 A, p. 78).

b. *Non-spherulitic rhyolite with microcrystalline or cryptocrystalline base.* — This type is also widely spread; it occurs in the neighbourhood of Ta'iz in Wady el-Barh and between Manakha and Wessil. Microscopically, the phenocrysts are mostly made of quartz and a few soda-sandine (5252), orthoclase-microperthite and albite (5243). The felspar is sometimes absent (5241). The quartz phenocrysts (about 1.32 mm.) are occasionally corroded or embayed and contain inclusions of the groundmass (5254). Some phenocrysts show graphic intergrowth of quartz and orthoclase (5255). The groundmass is microcrystalline (5243), sometimes coarse and granular (5285) or cryptocrystalline (5424). Roman described a comendite from Hadjelah which is similar to the preceeding type of rhyolite (1926, pp. 232-233). It is clear that the rhyolites of this type are leucocratic alkaline rhyolites with a potash soda felspar and rarely a separate soda felspar is present. Roman gave a chemical analysis of the rock, Table II column 3, which shows a lower content of Al_2O_3 than the average rhyolite of Daly (Table II column 5) and even than the alkaline rhyolites of the same group, the kalitordrillites of Johannsen (1932, vol. II, p. 61) emphasising their alkaline character.

c. *Glassy Rhyolites.* — These are divided into 3 structural types as follows :

1. Obsidians : This type of glassy rhyolite occurs in the south of Yaman at Ta'iz (5203), east of el-Qa'ada (5316), Dj. Gubah (5321), east of 'Ubal (5498), Dj. el-Shark (between Madinat el-'Abeed and San'aa — 5517) and between Manakha and Wessil (5888). In section the rock consists nearly completely of colourless or pale brownish glass, which shows, in some examples (5203), cryptocrystalline parts probably due to devitrification. Flow structure in the form of swirling lines is clear in some examples (5521). The R. I. of the glass is about 1.50 (5521). A few minute crystals of quartz (5275) or soda-sanidine (5521) are rarely present and form not more than 1 % of the

rock. Banded appearance is sometimes seen (5246). No chemical analysis of these obsidians is available and it is thus difficult to recognize their real nature, but they most probably represent the glassy exquivalents of the preceeding alkaline rhyolites especially as the scarce felspars present are represented by a soda sanidine.

2. Perlites : These occur at Ta'iz and represent the glassy types which show perlitic cracks. In the glass they carry crystals of sanidine and quartz (5279) or of oligoclase with about 20 % anorthite and sanidine (5263). A few crystals of augite which is faintly pleochroic from pinkish-violet to greenish-pink and may be titaniferous is rarely present (5263). The groundmass is of clear colourless (5279) or brownish (5263) glass that shows perfect perlitic cracks (pl. IX, fig. 18), with a R. I. of about 1.497 (5279). Roman (1926, p. 237) and Lamare (1930 A, p. 77) described similar perlites from the neighbourhood of San'aa.

3. Vitrophyres : This structural type is very widely spread in different regions of Yaman. It is found in the south of Yaman at Ta'iz (5205), between Madinat al-'Abeed and San'aa (5520), between Manakha and Wessil (5870), between Wessil and Hadjellah (5902) and between Hadjelah and 'Obal (5960).

Table II

	1	2	3	4	5	6
SiO_2	77.01	76.88	73.07	79.37	78.72	72.90
Al_2O_3	11.30	11.02	9.34	6.27	7.78	14.18
Fe_2O_3	1.63	1.80	6.98	4.14	4.39	1.65
FeO	0.25	0.36	0.37	0.60	1.31	0.31
MgO	0.04	—	1.34	0.40	—	0.40
CaO	0.15	0.74	2.04	2.57	traces	1.13
Na_2O	3.40	3.38	2.04	3.02	4.24	3.54
K_2O	5.47	4.77	3.12	3.65	3.03	3.94
H_2O +	0.39				0.31	1.33
H_2O −	0.07	0.64	1.08	1.09	0.22	
Co_2	0.01	0.23	—	—	—	—
TiO_2	0.15	—	0.16	—	0.31	0.48
P_2O_5	0.02	0.14	1.07	—	—	0.01
MnO	0.02	—	0.43	0.58	traces	0.13
Total	99.90	99.96	101.04	101.69	100.31	100.00

1. Rhyolite, I. 3(4).1.3. Ta'iz (5231). Analyst : Geochemical Lab., London.
2. Rhyolite, I. 3(4).1.3. Ta'iz (5231). Analyst : Chem. Dept. Cairo, Lab.

3. Rhyolite II. 3.2.3. Hadjeilah (Comendite of Roman 1926, p. 232). Analyst : I. Copuzeanu.
4. Rhyolite II.3(2).1.3. (2). Dj. Juioan, Wady Kadia (Comendite of Roman, 1926, p. 236). Analyst : I. Copuzeanu.
5. 'Pantellerite' with aegyrine. Hol Hol (railway of Harrar). (Lacroix 1923, p. 274). Analyst : M. Raoult.
6. Rhyolite I.3(4).(1) 2.3''. Average composition of Daly (1933).

Microscopically, the rock consists of phenocrysts of sanidine (5205), altered orthoclase-microperthite or albite (5520) together with few crystals of quartz in a glassy groundmass. In one example, however, the quartz (2.4—0.96 mm.) forms most of the phenocrysts (5960), which are often corroded and embayed and some show micrographic intergrowth of quartz and orthoclase (5238). The groundmass is formed wholly of glass with a R. I. of about 1.505 (5202). Occasionally (5870) the groundmass shows crystalline parts and is probably due to devitrification; the glass itself forming not less than 75 % of the base. Well developed flow structure is sometimes observed (5205). Imperfect microspherulites are occasionally present (5878) and a few badly developed perlitic cracks also occur (5520). A vitrophyric comendite described by Roman (1926, pp. 234-236) from Dj. Guioan at Wady Kadia (3 miles SW of Hadjeila) is related to the vitrophyres described above. Roman gave a chemical analysis of the rock (Table II, column 3) which shows an abnormally low content of Al_2O_3 (only 6.27 %) emphasizing its alkaline nature. It is not only lower than the kalitordrillite of Johannsen but is also lower, as far as the authors are aware, than any comendite or pantellerite described in the literature. It contains 4.62 % of acmite in the norm and is pantelleritic in nature with respect to its poverty in alumina. It is, however, poorer in its content of alkalies and is devoid of alkali metasilicates in the mode. It is chemically similar, in many respects, to a pantellerite from Somaliland (Table II, column 5) described by Lacroix (1923, Table p. 274, column A).

II. Trachytes.

The trachytes of Yaman show alkaline character The felspar is anorthoclase or soda-sanidine with rare albite or orthoclase-microperthite. Alkaline metasilicates are either present or absent.

1) Trachytes with soda-metasilicates : These rocks contain soda-amphibole or soda-pyroxene or both. Roman did not describe any soda metasilicates in the varieties of trachytes described by him (1926, pp. 240-247). The following types are distinguished in the present work :

a. *Riebeckite-trachyte.* — This type is present at Gabanet-el-Logeinat to the west of Ta'iz (5264). Microscopically, it consists of euhedral and often carlsbad-twinned phenocrysts of soda-sanidine (1.7 mm.) and rare anorthoclase in larger crystals (2.6 mm.) in a trachytic groundmass. Uniformly distributed through the slide are moss-like scrystals of riebeckite which occasionally occurs in plates with distinct cleavage. The groundmass is holocrystalline consisting of numerous short laths of sanidine which show subparallel arrangement. Riebeckite and aegirine-augite are also present in the groudmass. The percentages of the modal minerals are as follows :-

Sanidine	77.5 %
Anorthoclase	10 %
Iron-ores (magnetite, haematite)	3 %
Riebeckite	9.5 %

A chemical analysis of the rock is given (Table III, columns 1 and 2). It shows a higher content of SiO_2 and a lower content of Al_2O_3 than Daly's average for alkaline trachytes (Table III, column 7). It approaches in this respect the group of kalirhyolites of Johannsen (1932, pp. 62-68) and could be considered as transitional between the kalirhyolites and the kalitrachytes (*op. cit.*, pp. 18-20).

b. *Anorthoclase soda-trachyte.* — This type occurs at Ta'iz (5209-5211) and differs from the previous type in being rich in anorthoclase. In slide, the rock shows porphyritic crystals of anorthoclase, some albite (8 % An) together with few flakes of a dark brown biotite in a holocrystalline groundmass consisting of laths of anorthoclase and the fine magnetite or haematite due to the alteration of the metasilicates.

TABLE III

	1	2	3	4	5	6	7
SiO_2	69.74	68.18	69.94	69.06	63.10	68.28	62.63
Al_2O_3	14.16	11.64	14.43	15.01	17.22	17.08	17.06
Fe_2O_3	2.86	5.60	2.30	1.65	4.10	1.58	3.01
FeO..............	0.29	0.36	0.57	1.37	0.27	1.03	1.98
MgO	0.28	0.72	0.27	0.14	0.80	0.14	0.63
CaO..............	0.61	1.12	0.40	0.74	1.18	0.26	1.51
Na_2O.............	4.68	4.19	5.33	5.34	5.39	5.68	6.26
K_2O	5.29	4.72	5.01	4.79	3.10	4.62	5.37
H_2O +............	1.07		0.56			0.72	
		1.70		0.06	3.36		0.71
H_2O −	0.29		0.18			0.41	
CO_2..............	0.17	0.90		1.01	0.97		
TiO_2..............	0.25	0.50	0.60	0.60	0.19	0.23	0.62
P_2O_5	0.05	0.28	0.10	—	0.30	0.10	0.09
MnO.............	0.05	0.08	0.08	0.05	0.08	—	0.13
Total............	99.79	99.99	99.77	99.82	100.06	100.13	100.00

1. Riebeckite trachyte. I.4.1.3''. W. Ta'iz (5264). Analyst : Geochem. Lab. London.
2. Riebeckite trachyte. I(2).4.1.3. W. Ta'iz (5264). Analyst : Chem. Dept. Lab. Cairo.
3. Anorthoclase soda-trachyte (5209). I.4.1.3(4). Ta'iz. Analyst : Geochem. Lab. London.
4. Anorthoclase soda-trachyte (5209). I.4.1.4(3). Ta'iz. Analyst : Chem. Dept. Lab. Cairo.
5. Quartz soda-trachyte (5258). I''.4.2(2)4. Ta'iz. Analyst : Chem. Dept. Lab. Cairo.
6. Quartz riebeckite trachyte. I.4'.1.(3)4. Madagascar. Analyst : Boiteau (Lacroix 1923, p. 24).
7. Alkaline trachyte, average composition, Daly (1933).

The anorthoclase has a (-) 2V ranging from 46° (5211) to 52° (5209) and in section parallel to 001, the extinction angle is about 2° measured from the trace of 010. The groundmass shows trachytic texture, and contains few minute crystals of katophorite or aegyrine-augite beside scarce interstitial patches of quartz (5209).

An exmple (5209) gave the following approximate percentages of modal minerals :

Quartz	4 %
Anorthoclase	74.2 %
Albite	5.1 %
Iron-ores (mostly altered metasilicates)	15.5 %
Chlorite and biotite	1.2 %

Its chemical analysis is given in Table III, columns 3 and 4, which shows that it is similar to the preceeding type (riebeckite treckyte) except that it is slightly richer in Na_2O. Prior (1900 B, p. 94) described a similar rock from Mt. Kishyat in Abyssinia.

A quartz soda-trachyte (5258) from Ta'iz (N. of Dj. Saber) is similar but is richer in quartz. A quantitative measurement gave the following :

Quartz..	8.5 %
Anorthoclase and albite	64.5 %
Magnetite and haematite (after riebeckite)..........	27 %

Chemical analysis of the same is given in Table III column 5. This is anologous with Daly's average of alkaline trachyte (Table III, column 7). Its low content of SiO_2 and high content of Al_2O_3 and Fe_2O_3 in comparison with the two previous analyses seem to be due to the alteration of the felspars into kaolin.

An analysis of a 'quartz riebeckite trachyte' (Table III, column 6) described by Lacroix (1923, pp. 16-17) from Madagascar is related to the alkaline trachytes of Yaman. Mineralogically, it resembles to some extent pantelleritic trachytes from Kenya and Pantelleria (Zeneti type) especially those rather rich in free quartz (Smith 1931, pp. 222-224).

2) TRACHYTES DEVOID OF SODA-METASILICATES : These rocks are also alkaline as is evident from the type of felspar which is soda-orthoclase, anorthoclase, orthoclase-microperthite or albite but they do not contain any soda-amphiboles or soda-pyroxenes.

The following two types are distinguished in the present work :

a. *Hololeucrocratic trachyte.* — This type also occurs at Ta'iz, N.W. of Dj. Saber. It carries few small porphyritic crystals of orthoclase-microperthite and albite of about 1.3-2.5 mm. in diameter. The groundmass is nearly hololeucocratic except for very little magnetite dust and scarce green chlorite, and consists of laths of orthoclase which are subparallelly arranged showing typical trachytic texture (5309). Roman (1926, p. 240) described similar rocks from Wady Seham at 'Obal.

b. *Glassy trachyte.* — This type collected from Wady Hawban to the NNE of Dj. Saber is vesicular and porphyritic. Microscopically, it shows few large phenocrysts of anorthoclase or soda-orthoclase of about 1.5 mm. in diameter embedded in a brown glassy groundmass (R. I. about 1.52) containing minute felspar microlites and crystallites and showing a few small vesicles (5269). A few brown plates of a dark mica (pleochroic from dark-brown to pale-brown and has a refractive Index of about 1.56) are also present.

Two chemical analyses (not shown in the Table) of these trachytes devoid of soda-metasilicates showed that they possess alkaline characters and that they are very akin to the trachytes that carry soda-metasilicates.

III. Trachyandesites.

These include rocks containing oligoclase-andesine felspars together with potash felspars. The following two types of trachyandesites are distinguished in the present work :

1) Trachyandesite poor in ferromagnesia : This occurs in Wady 'Ubal and carries phenocrysts of acid andesine of about 32 % An in a groundmass consisting of orthoclase, oligoclase-andesine of about 28 % An together with very little green chloritic matter (5496). Andesine occurs in numerous large prismatic crystals of about 2.12 mm. in diameter. The groundmass is hololeucocratic except for little magnetite and chlorite and has a subtrachytic to fine granular structure. It consists of short laths or microlites of oligoclase-andesine together with numerous patches or interstitial crystals of orthoclase and few acicular prisms of apatite.

Roman (1926, p. 245) described from Manakha a « Plagitrachyte» as transitional towards trachyandesites; its chemical analysis is given in Table IV, column 1. It shows a lower percentage of Al_2O_3 and Na_2O and a higher content of Fe_2O_3 than Daly's average for trachyandesite (Table IV, column 3). Roman (1926, p. 251) also described a trachyandesite from Manakha the chemical analysis of which is given in Table IV, column 2. It is also poor in Al_2O_3 and rich in Fe_2O_3 when compared with the average given by Daly, but the percentages of the alkalies are about the same.

2) Biotite-hornblende-trachyandesite : This type is present in Ta'iz and carries phenocrysts of andesine of about 37 % An together with numerous plates of biotite, some crystals of brown and pale green hornblende, in a hyalopilitic very fine groundmass consisting of minute microlites of oligoclase, some orthoclase and little glass.

Table IV

	1	2	3
SiO_2	55.95	57.08	57.84
Al_2O_3	13.52	12.65	17.24
Fe_2O_3	12.20	9.21	3.97
FeO	0.85	0.30	3.18
TiO_2	—	—	1.11
MgO	0.71	3.76	1.25
CaO	6.17	5.49	4.20
Na_2O	2.79	5.92	5.67
K_2O	4.23	3.46	3.62
H_2O +	0.61	1.03	1.30
H_2O –			
P_2O_5	1.13	0.07	0.57
MnO	1.64	1.04	0.05
Total	99.80	100.01	100.00

1. Trachyandesite II.4.2.3. Manakhah. Analyst : N. Metta (Plagitrachyte of Roman, 1926, p. 246).
2. Trachyandesite II.5.1.4. Manakhah. Analyst : N. Metta (Roman, 1926, p. 251)
3. Trachyandesite, average composition, Daly (1933).

Andesine occurs in large crystals, of about 2.6 mm. in diameter, that occasionally show zoning (5287). The brown hornblende occurs in small plates ranging from 0.16 mm. to 0.64 mm. in diameter. It is pleochroic from brown to pale-brown or yellowish-pink with $-2V = 84°$ and $Z^\wedge c = 13°$. Large crystals of slightly pleochroic pale-green hornblende are also present, varying from 0.5 mm. to 1 mm. in diameter, and is later than the brown variety.

Roman (1926, p. 252) described a 'trachyandesite proper' from Bohak in Dj. Dhamir (E. of Badjel). He did not, however, describe any potash felspar in it and the rock could possibly be an andesite.

IV. Basalts.

The basalts are very widely distributed at numerous localities along the whole country covered by the present Expedition. They range from types related to trachybasalts to more basic types represented by ankaramites. The different types are described as follows :

1) Leucocratic basalts (Types related to trachybasalts) : These basalts are usually leucocratic, rich in felspar and poor in coloured minerals and chemically they have affinities with the trachybasalyts. According to their structure they can be divided into :

a. *Porphyritic types.* — These porphyritic basalts are good marker beds and are widely distributed in southern and central Yaman.

Microscopically, the rock usually carries numerous large porphyritic crystals of labradorite (52 % An) ranging from 2.12 mm. (5266) to 15.9 mm. (5310) in diameter, and forming 6.5 % (5266) to 61.8 % (5310) of the whole rock. Epidote is commonly present as aggregates of small crystals, as inclusions in the felspar phenocrysts or filling vesicles (5292). Occasional crystals of green hornblende are present (5292). Amygdales contain epidote (5310), green chlorite (5141), both epidote and chlorite (5292), chlorite and quartz (5292) or quartz only (5266).

The groundmass showing intersertal or pilotaxitic structure, is formed of microlites of acid labradorite which is usually more acidic than the phenocrysts, together with grains of magnetite, chlorite-flakes, epidote, and occasional calcite. Scarce, allotriomorphic and small crystals of orthoclase may be present. A chemical analysis of this type (5310) is given in Table V, column 1. It shows affinities towards the trachybasalts and is richer in alkalies (especially K_2O) and Al_2O_3, and poorer in MgO and CaO than Daly's average of basalts (Table V, column 11).

Another chemical analysis of the same type of rock (5292) is given in Table V, column 2 and is similar to the previous analysis.

Roman (1926, p. 267) described two types of 'trachydolerites' from San'aa and from 'Obal (*op. cit.*, p. 262). Their chemical analyses

(Table V, columns 3 and 4) compare with that of the present type (specially in the high alkali content), but are poorer in Al_2O_3.

Lamare (1930 *A*, p. 75) described porphyritic basalts, approaching andesites, which are comparable in many respects to the present type.

b. *Nonporphyritic types.* — These are also widely distributed and are very similar to the preceeding type except in being nonporphyritic. They are usually vesicular or amygdaloidal. The groundmass occasionally contains glass and shows a hyalopilitic texture (5233).

2) Normal Basalts : These are olivine-free basalts ; they consist of basic plagioclase and pyroxene. Several structural types are described : (See Table V on page 20).

a. *Porphyritic types.* — These basalts are common in central and southern Yaman. Under the microscope (pl. X, fig. 19) it carries phenoscrysts (1.3-8 mm.) of basic plagioclase mostly labradorite : 58 % An in (5469) and 71 % An in (5216). Porphyritic crystals of augite (1.5-4.2 mm.) are sometimes present with $+2V = 55°$ and $Z\hat{\ }c = 48°$. It is pale pinkish-brown titaniferous variety, slightly pleochroic, and occasionally shows zoning. The phenocrysts of felspar and augite form about 30 % of the whole rock.

The groundmass consists of microlites of labradorite of about 50 % An, small crystals of pale brownish augite and numerous magnetite octahedra. Some glass is occasionally present in the groundmass (5504). Vesicles about 2 mm. in diameter either filled with chlorite (5436) or calcite, epidote and quartz (5469) are present.

The mode of the rock (5469) is :

Labradorite	50 %
Augite	12 %
Magnetite and ilmenite	22 %
Chlorite	8 %
Calcite and epidote	8 %

A chemical analysis of this type (5469) is given in Table V, column 5. It differs from the average in being richer in CaO and poorer in

TABLE V

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2..	49.44	48.72	47.84	48.00	45.10	49.38	45.06	39.72	41.82	42.62	48.78	43.82
Al_2O_3 .	17.10	19.49	13.08	16.48	12.79	17.05	16.70	13.03	11.07	11.31	15.85	8.81
Fe_2O_3.	7.40	7.22	8.04	10.15	4.53	8.18	4.98	0.72	8.59	8.25	5.37	3.08
FeO .	3.41	3.59	6.96	2.40	8.17	6.15	7.74	13.84	10.10	5.03	6.34	8.01
MgO..	3.24	1.20	3.41	2.55	6.01	1.92	3.25	11.32	5.32	8.24	6.03	15.50
CaO .	7.69	7.46	10.08	11.42	10.90	13.80	8.90	14.04	18.47	14.87	8.91	13.50
Na_2O .	3 22	4.85	4.23	4.20	2.78	0.97	3.71	1.35	1.31	1.25	3.18	1.51
K_2O ..	2.31	2.64	2.55	1.13	0.84	1.42	0.52	0.17	0.84	0.89	1.63	0.87
H_2O +	2.35									2.96		
		1.69	0.87	1.19	3.20	0.36	2.33	2.88	0.76		1.76	1.17
H_2O -.	0.52									0.99		
CO_2 .	—	0.42	—	—	0.54	—	1.33	0.14	—	0.51	—	—
TiO_2 .	2.48	2.60	0.12	—	5.20	0.17	5.20	3.00	1.05	2.54	1.39	3.32
P_2O_5 .	0.65	0.25	1.35	—	0.13	0.96	0.32	0.20	0.55	0.33	0.47	0.41
MnO.	0.15	—	1.12	3.22	0.06	1.30	0.10	0.03	1.05	0.27	0.29	—
Total.	99.96	100.13	99.65	101.14	100.25	101.66	100.14	100.44	100.93	100.06	100.00	100.00

1. Leucorcatic basalt (5292), II.5.3.''.4 Ta'iz. Analyst Geochem. Lab. London.
2. Leucocratic basalt (5310), Ta'iz. II.5.3.4. Analyst Chem. Dept. Lab. Cairo.
3. Trachydolerite, III.5.2.4. San'aa. Analyst N. Metta (Roman, 1926, p. 267).
4. Trachydolerite. II.5.3.4. 'Ubal. Analyst I. Copuzeanu (Roman 1926, p. 262).
5. Normal basalt. III.5.3''.4''. (5469), Heis. Analyst Chem. Dept. Lab. Cairo.
6. Normal basalt. II.4.4.3. Wessil. Analyst N. Metta (Trachyandesite of Roman, 1926, p. 254).
7. Olivine basalt (5307). II''.5.3(4). ''5. Ta'iz. Analyst Chem. Dept. Lab. Cairo.
8. Ankaramitic basalt (5553). (III) IV.1(2).2.(2) 3. San'aa. Analyst. Chem. Dept. Lab. Cairo.
9. Ankaramitic basalt. IV.2.4.(4). San'aa (Trachydolerite of Roman, 1926, p. 268).
10. Ankaramite (5795). III (IV).5.4.''4. Mafhaq. Analyst Goechem. Lab. London.
11. Basalt, average composition, Daly (1933).
12. Ankaramite, average composition, Daly (1933).

alkalies, specially K_2O. It also shows a distinctly high content of TiO_2.

Roman (1926, p. 253) described a so-called « trachyandesite », which is related to the above type both in its mineralogy and chemistry. A chemical analysis of the rock (Table V, column 6) compares closely with Daly's average for basalts except for being much poorer in Na_2O and MgO and richer in CaO.

b. *Non-porphyritic types.* — These are further sub-divided into the following structural varieties :

1. BASALTS SHOWING SUB-OPHITIC STRUCTURE : This variety, occurring at Dj. Bihan, consists of stout laths of labradorite and augite exhibiting sub-ophitic structure (5446). Few rounded amygdales, about 1.2 mm., filled with calcite are present.

2. BASALTS WITH INTERGRANULAR STRUCTURE : Under the microscope, this type, which occurs at Dj. Gubah' (5523) and Dj. Mogash (5531) consists of laths of acid-labradorite (54 % An) and pinkish-brown grains of augite that occur in the interstices between the felspar laths showing intergranular structure (plate X, fig. 20). Interstitial chlorite and magnetite octahedra are also present.

3. VERY-FINE GRAINED BASALTS : This type which occurs at Dj. Saber (5270) and at Dj. Mogash (5523) consists of very minute microlites of plagioclase together with small grains of augite. Magnetite is uniformly scattered about the whole rock in the form of minute grains or octahedra. Very scarce porphyritic crystals of pale pinkish-brown augite with $+2V=52°$ and $Z^c=44°$ (5270) are occasionally present. Brown mica, chlorite and calcite occur as accessories. Lamare (1930 A, p. 76) described a fine-grained basalt akin to the present type, from Dj. Nougoum.

3) OLIVINE BASALTS : These olivine-basalts, which are widely distributed, contain olivine in addition to the minerals of the normal basalts. Olivine is usually present as phenocrysts but may also occur as a second generation in the groundmass. It is rich in magnesia (about 82 % Mg_2-

SiO_4) with — $2V = 88°$ (5307). The pyroxene is represented by pale-brown augite as in the normal basalts, with $+2V = 56°$ and $Z^c = 48°$. The olivine basalts show the same structures as the normal types. Porphyritic (pl. XI, fig. 21) and non-porphyritic types showing intergranular or ophitic structures are present. The mode of a porphyritic example (5412) is :

Labradorite	46.6 %
Augite	32.8 %
Bowlingite (mostly altered olivine)	10.7 %
Magnetite and haematite	9.8 %

A chemical analysis of an example of the ophitic variety (5307) is given in Table V, column 7, and its mode is :

Labradorite	62.2 %
Pyroxene	13.5 %
Olivine	8.1 %
Serpentine and chlorite	5.4 %
Magnetite and ilmenite	10.8 %

It shows an abnormally low content of MgO and is also poor in K_2O, but the sum of alkalies is nearly the same as that of Daly's average for basalts (Table V, column 11). It shows a high percentage of TiO_2 and is similar in this respect to the normal basalts (Table V, column 5).

4) MELANOCRATIC BASALTS RICH IN PYROXENES : These are divided into types approaching ankaramites (pyroxene forming 30 %-50 %) and ankaramites proper containing more than 50 % of pyroxenes.

a. *Basalts approaching ankaramites.* — These are divided into porphyritic and non-porphyritic types :

1. PORPHYRITIC TYPES: These basalts were collected from Dj. ʿAsser (5553) and from Dj. Dhamir (6019). Porphyritic crystals of augite and olivine are present in a groundmass of labradorite microlites, augite, small crystals of olivine and magnetite octahedra showing an intergranular structure. The pyroxene phenocrysts vary between 2.65 mm. (6019) and 5.3 mm. in diameter (5553) and may occasionally reach up to 7.4 mm. (5553). It is either diopsidic augite with $+2V = 58°$ and $Z^c = 44°$ (6019) or is pinkish-brown titaniferous augite with a faint pleochrism (5553). The coloured augite has a larger extinction angle, with $Z^c = 52°$. Olivine is either fresh or is altered specially round its borders into pleochroic bowlingite (5477). Olivine phenocrysts vary between 2.1 mm. (6019) and 3.2 mm. in diameter (5553) and are rich in magnesia (89 % Mg_2SiO_4) having $+2V = 89°$. A quantitative measurement of the modal minerals (5553) gave the following percentages :

Labradorite	23 %
Augite	49.5 %
Olivine	13.5 %
Magnetite	14 %

A chemical analysis of the same rock is given in Table V column 8. It is comparable with Daly's average for ankaramite (Table V, column 12) but is richer in Al_2O_3 and poorer in MgO than the latter.

Roman (1926, p. 268) described a « trachydolerite » from San'aa and gave a chemical analysis of it (Table V, column 9). Because of its mineral and chemical composition it is better attributed to the basalts. Its chemistry is comparable with the ankaramitic basalt analysed in the present work but is much poorer in MgO.

Lamare (1930 A, p. 76) described basalts approaching ankaramites from Madbah near San'aa.

2. NON-PORPHYRITIC TYPES : These are devoid of porphyritic crystals and show intergranular (5457) or ophitic structures (5586).

b. *Ankaramites.* — This type consists of pyroxene, which forms more than 50 % of the whole rock, olivine, labradorite which forms less than 15 % of the rock, and iron-ores.

Quantitative measurements show that it contains 62 % (5795)-66 % (5495) pyroxene; 16 % (5590)-20 % (5495) olivine, 5 % (5495)-14 % (5795) labradorite; 7 % (5590)-10 % (5495) iron-ores.

The pyroxene occurs in large idiomorphic phenocrysts (plate XI, fig. 22) which vary between 1 mm. (5487) and 3.5 mm. (5495) in diameter. It sometimes occurs in numerous smaller crystals of about 0.7 mm. (5811) to 0.8 mm. (7595) in diameter. It varies from very pale green diopside or diopsidic augite with $+2V = 58.5°$ and $Z^c = 39°$ (5495) to dark pinkish-brown or pale violet faintly pleochroic augite or titaniferous augite with $+2V = 56°$ and $Z^c = 49°$ (5590). Both types are sometimes present together (5495), in which case the coloured is the younger. Large crystals of pyroxene show zoning, the centre is usually pale-green diopside or diopsidic-augite surrounded by an outer border of dark brownish augite or titaniferous-augite (5495). They occasionally show twinning and sometimes include grains of olivine and magnetite.

Olivine is found in well developed idiomorphic crystals, that vary between 0.8 mm. (5590) and 2.65 mm. (5495) in diameter, with $+2V = 85°$ (5495) or 87° (5590).

The groundmass is compact and is composed of numerous grains of augite, magnetite octahedra, olivine and very minute microlites of labradorite. The mode of one example (5795) gave :

Labradorite	14 %
Pyroxene	62 %
Magnetite	7.5 %
Serpentine (mostly after Olivine)	16.5 %

A chemical analysis of the same rock (5795) is given in Table V, column 10. It compares with the average of ankaramites given by Daly (Table V, column 12) but is poorer in Mgo as in the case of basalts approaching ankaramites (Table V, column 8). This is probably due to the calcic nature of the pyroxenes.

b. *The Pleistocene Volcanic Rocks.*

Lamare (1930 A, p. 76) is the only one—as far as the authors are aware—who has described the Pleistocene Volcanic rocks of Yaman. He

described three types of 'recent and subrecent' olivine-basalts from the neighbourhood of San'aa.

In the present contribution these rocks were found to vary from the more basic olivine basalts to the less basic divine trachy-basalts.

I. Olivine-trachy-basalts

This type occurs in Belad Hamdan (5598), between Dj. Dhein and ʿAmran, north of Sanʿaa (6294) and at Dtharwan (6298). They represent basic rocks carrying olivine but are also rich in alkalies and contain orthoclase felspar. In slide, they show trachytic to pilotaxitic structures and are almost non-porphyritic. They are formed of sub-parallel laths of andesine or basic oligoclase, olivine, little pyroxene and magnetite octahedra. The felspar forms some 50 % of the rock whereas the olivine forms about 20 % and is fayalitic with $-2V = 73°$ (about 42 % FeO). The pyroxene, when present, is represented by a pale green diopsidic-augite. Some of the felspar microlites are untwinned or show simple twinning and probably represent orthoclase. They seem to form transitional types between mugearites proper and olivine basalts. A chemical analysis of the type (5598) is shown in Table VI, column 1. It is rich in alkalies, poor in magnesia and lime and resembles the more basic types of oligoclase basalt (trachy-dolerites) described by Edwards from Central Victoria (1938, p. 270, table III, column 1) and is related to the mugearites.

II. Olivine basalts

The essential constituents of these basalts are basic plagioclase which range from labradorite to bytownite, olivine, monoclinic pyroxene together with magnetite. The rocks are often nonporphyritic. Felspar phenocrysts are rarely present (5594) and are generally more calcic than the felspar of the groundmass. The felspar is basic plagioclase usually labradorite of about 65 % An. Inclusions are usually irregular patches of devitrified or brownish glass ; gas inclusions are also common.

TABLE VI

	1	2	3	4	5	6	7
SiO_2	54.52	46.12	44.04	46.08	46.72	49.20	48.78
Al_2O_3	16.74	16.92	14.91	17.38	19.00	16.65	15.85
Fe_2O_3	5.87	2.14	2.26	4.82	12.25	4.76	5.37
FeO ,,.......	5.64	8.33	9.36	6.18	0.64	5.36	6.34
TiO_2	0.90	1.19	1.30	1.00	0.90	1.68	1.39
MnO........	0.24	0.19	0.18	0.16	0.19	0.55	0.29
CaO	5.00	11.41	10.41	9.30	9.90	7.74	8.91
MgO........	1.45	9.30	5.79	7.28	5.36	4.43	6.03
BaO	—	—	—	—	—	—	—
Na O	4.63	2.40	2.63	1.99	2.98	4.54	3.18
K_2O	2.32	0.31	1.16	0.58	0.87	3.19	1.63
S...........	0.028	—	0.055	0.017	0.055	—	—
P_2O_5........	0.77	0.16	1.15	0.64	0.13	0.60	0.47
Cl	0.007	—	0.075	0.018	0.018	—	—
H_2O +.......	1.41	0.97	6.80	4.33	1.39	—	—
H_2O –	0.94	0.26	0.60	0.77	0.56	1.30	1.76
CO_2.........	trace	0.25	trace	trace	trace	—	—
Total........	100.465	99.95	100.72	100.545	100.913	100.00	100.00

1. Olivine trachy-basalt (5598), II. ''5.(2)3.4. Hamdan, Pleistocene. Analyst Chem. Dept. Lab. Cairo.
2. Olivine-basalt (5559). ''III.5.4.''5. Dj. El-'Samaa'-Hamdan. Analyst Geochem. Lab. London.
3. Olivine basalt (5770). (II) III.5.(3)4.4. Hugga. Analyst Chem. Dept. Lab. Cairo.
4. Olivine basalt (5540). (II) III.5.4.4''. Kaulet el 'Erg, San'aa. Analyst Chem. Dept. Lab. Cairo.
5. Olivine basalt (5601). (II)''.5.4.4''. Between Na'it and 'Amran. Analyst Chem. Dept. Lab. Cairo.
6. Trachydolerite, average composition, Daly (1933).
7. Basalt, average composition, Daly (1933).

Olivine is always present with—2V = 79° which indicates that the olivine is somewhat fayalitic containing 34 % Fe O (5535). It is usually idiomorphic and shows prismatic faces and pyramidal terminations. It is colourless when fresh (which is often the case in the glassy varieties of olivine-basalts), but in many cases it is slightly altered to red iron-oxide or to iddingsite along the peripheries of the crystals. With increased alteration (5534), the red colouration extends further in, so that small grains are entirely red while larger crystals show fresh centers.

The pyroxene is always monoclinic. In most cases it is pinkish-brown diopsidic-augite with + 2V = 56° and Z^c = 42° (5766). Sometimes augite is darker in colour showing faint pleochroism and is titaniferous (5573). In most cases it occurs only in the groundmass but occasionally it occurs in two generations. Hour-glass structure is rarely present (5766). Sometimes the pyroxene crystals are aggregated in clusters or glomeroporphyritic groups (5595). In most of the glassy types of basalts, pyroxene is completely absent (5772).

According to the structure of these olivine-basalts, they are classified into the following types :

1. BASALTS SHOWING OPHITIC OR SUB-OPHITIC STRUCTURE : This type occurs at Dj. El-Samaa (from Saylet el-Bawareek and El-Mosseirega) and at Wady al-Kharid. The groundmass is nearly holocrystalline and consists of stout lath-shaped labradorite felspars (of about 0.8 mm. in length and 0.1 mm. in thickness) with large poeckilitic crystals of augite or titaniferous-augite filling the interstices (pl. XII, fig. 24). Olivine is present in numerous large euhedral crystals (0.5-1 mm.) usually slightly altered to iddingsite along cracks and borders (5558). The mode of one example (5559 is as follows :

Labradorite	44.2 %
Olivine	26.4 %
Pyroxene	23.5 %
Magnetite	5.8 %

A chemical analysis of the same specimen (5559) is given in Table VI, column 2. This compares fairly closely with Daly's average of basalts (Table VI, column 7) except for containing a somewhat higher percentage of CaO and MgO and in being poorer in alkalies, and is related to olivine basalt magma type.

2. BASALT SHOWING INTERGRANULAR STRUCTURE : This type is present to the north of San'aa : at Dj. Haid el-Ahmer (5534) and at Kaulet el-'Erg (5535), in Hamdan, at El-Haifa (5593) and to the north of Arhab near Ma'amar (5756). In this type the interstitial pyroxene grains occur in aggregates and not in large crystals in optical continuity. Olivine

usually appears in crystals of about 1.2 mm. in diameter. The felspar laths are of about 1.5 mm. in diameter and are arranged in a network that may be diverse, sub-parallel or sometimes radial (5756). The percentages of the different constituents (5594) are as follows :

Labradorite	42.4 %
Olivine	27.2 %
Pyroxene	21.2 %
Magnetite	9 %

This and the preceding type are relatively rich in olivine with respect to the pyroxenes and are different in this respect from the Tertiary olivine basalts.

Lamare (1930 A, p. 76) described from the cone of Darouan (in the neighbourhood of San'aa) and from Dj. Dhein olivine basalts related to the types described.

3. Basalts showing intersertal to hyalo-ophitic structures : This type occurs at Ma'amar (5755), Hugga (5769) and at Kaulet el-'Erra (6288). In this type of rock, the interstices between the adjacent laths of labradorite contain a glassy matter. Its mode (5770) is different from the two preceding types as it contains greater amounts of pyroxene than olivine :

Labradorite	31 %
Pyroxene	28 %
Glass	6 %
Olivine	15.5 %
Magnetite	19.5 %

A chemical analysis of this type (5770) is given in Table VI, column 3. It is on the whole analogous to that of the olivine basalt showing ophitic structure (Table VI, column 2) and is closer to Daly's average.

4. Glassy basalts : These are widely distributed in Belad Hamdan. The rocks are glassy and are usually porous or vesicular. They occur in two varieties : a variety showing a hyalopilitic structure, and a more glassy variety. This latter consists of vesicular black glass with few laths of labradorite, olivine (5539), and occasional crystals of dark pinkish-brown augite (6287) of about 2.12 mm. in diameter. Some of the glassy types occur as volcanic bombs with the characteristic twisted shape, at the top of the cones, *e.g.*, of Kaulet el-'Erg (5538 and 5539). These volcanic bombs have a diameter ranging from 21 to 25 cms. The following is a common mode (5540) :

Labradorite	11.8 %
Olivine	17.6 %
Glass and iron ores	70.6 %

Two chemical analyses of this glassy olivine-basalt are given in Table VI, columns 4 and 5. They show that they correspond to an olivine basalt magna type.

Lamare (1930 A, p. 76) described a glassy basalt from Heziz volcano (in the neighbourhood of San'aa) which is related to the above type.

See Table VII on pages 158-159.

TABLE VII

	1	2	3	4	5	6	7	8	9
SiO_2	73.42	79.37	77.01	73.07	71.69	69.74	63.10	69.94	57.08
Al_2O_3	10.49	6.27	11.30	9.34	10.75	14.16	17.22	14.43	12.65
Fe_2O_3	1.72	4.14	1.63	6.98	4.44	2.86	4.10	2.30	9.21
FeO	0.97	0.60	0.25	0.37	0.44	0.29	0.27	0.57	0.30
MgO	—	0.40	0.04	1.34	0.53	0.28	0.80	0.27	3.76
CaO	2.22	2.57	0.15	2.04	2.57	0.61	1.18	0.40	5.49
Na_2O	4.56	3.02	3.40	2.04	4.46	4.68	5.39	5.33	5.92
K_2O	4.20	3.65	5.47	3.12	4.19	5.29	3.10	5.01	3.46
H_2O+	1.88	1.09	0.39	1.08	0.88	1.07	3.36	0.56	1.03
H_2O-	—	—	0.07	—	—	0.29	—	0.18	—
CO_2	0.70	—	—	—	—	0.17	0.97	—	—
TiO_2	—	—	0.15	0.16	—	0.25	0.19	0.60	—
P_2O_5	0.27	—	0.02	1.07	—	0.05	0.30	0.10	0.07
MnO	0.05	0.58	0.02	0.43	0.86	0.05	0.08	0.08	1.04
Total	100.48	101.69	99.90	101.04	100.81	99.79	100.06	99.77	100.01
Q	31.36	50.34	36.06	45.54	27.84	20.94	17.04	19.14	1.98
or	25.02	21.13	32.80	18.35	25.02	31.14	18.35	29.47	20.57
ab	30.39	12.05	27.25	17.29	31.44	39.82	45.59	45.06	46.11
an	—	—	—	4.17	—	1.95	3.89	0.56	—
ne	—	—	—	—	—	—	—	—	—
lc	—	—	—	—	—	—	—	—	—
c	—	—	—	1.12	—	—	2.86	—	—
ac	5.08	4.62	1.39	—	4.62	—	—	—	3.70
ns	0.61	1.83	—	—	0.37	—	—	—	—
di	3.48	—	0.22	—	—	0.70	—	0.43	—
wo	0.35	5.22	—	—	5.34	—	—	—	11.14
hy	—	1.00	—	3.20	1.72	—	2.00	0.50	9.50
ol	—	—	—	—	—	—	—	—	—
os	—	—	—	—	—	—	—	—	—
mt	—	3.71	0.23	2.09	4.18	0.23	0.46	0.23	4.41
hm	—	—	0.96	5.60	—	2.72	3.84	2.08	4.96
il	—	—	0.30	0.30	—	0.46	0.46	1.22	—
ap	0.67	—	—	2.17	—	—	0.67	0.34	0.34

	10	11	12	13	14	15	16	17	18	19	20
SiO_2	55.95	49.44	48.72	49.38	48.00	47.84	45.10	45.06	41.82	39.72	42.62
Al_2O_3	13.52	17.10	19.49	17.05	16.48	13.08	12.79	16.70	11.07	13.03	11.31
Fe_2O_3	12.20	7.40	7.22	8.18	10.15	8.04	4.53	4.98	8.59	0.72	8.25
FeO	0.85	3.41	3.59	6.15	2.40	6.96	8.17	7.74	10.10	13.84	5.03
MgO	0.71	3.24	1.20	1.92	2.55	3.41	6.01	3.25	5.32	11.32	8.24
CaO	6.17	7.69	7.46	13.80	11.42	10.08	10.90	8.90	18.47	14.04	14.87
Na_2O	2.79	3.22	4.85	0.97	4.20	4.23	2.78	3.71	1.31	1.35	1.25
K_2O	4.23	2.31	2.64	1.42	1.13	2.55	0.84	0.52	0.84	0.17	0.89
H_2O+	0.61	2.35	—	0.36	1.19	0.87	3.20	2.33	0.76	2.88	2.96
H_2O-	—	0.52	1.69	—	—	—	—	—	—	—	0.99
CO_2	—	—	0.42	—	—	—	0.54	1.33	—	0.14	0.51
TiO_2	—	2.48	2.60	0.17	—	0.12	5.20	5.20	1.05	3.00	2.54
P_2O_5	1.13	0.65	0.25	0.96	—	1.35	0.13	0.32	0.55	0.20	0.33
MnO	1.64	0.15	—	1.30	3.22	1.12	0.06	0.10	1.05	0.03	0.27
Total	99.80	99.96	100.13	101.66	101.14	99.65	100.25	100.14	100.93	100.44	100.06
Q	15.10	4.32	—	10.38	—	—	—	2.80	—	—	—
or	25.00	13.34	15.57	8.34	6.67	15.01	5.00	2.78	5.00	—	5.56
ab	23.60	27.25	33.51	8.38	35.63	36.15	23.58	31.44	11.00	—	10.48
an	12.20	25.58	23.63	37.25	22.80	9.45	19.74	27.52	21.68	28.91	22.52
ne	—	—	3.98	—	—	—	—	—	—	5.96	—
lc	—	—	—	—	—	—	—	—	—	0.87	—
c	—	—	—	—	—	—	—	—	—	—	—
ac	—	—	—	—	—	—	—	—	—	—	—
ns	—	—	—	—	—	—	—	—	—	—	—
di	—	6.70	6.48	20.45	8.64	0.23	24.86	5.07	21.48	26.67	36.29
wo	5.00	—	0.35	—	—	—	—	—	—	—	—
hy	1.80	5.00	—	1.16	—	—	6.02	7.29	—	—	2.60
ol	—	—	—	—	2.95	12.26	—	—	10.52	25.78	0.84
os	—	—	—	—	—	—	—	—	—	1.80	—
mt	8.10	4.18	3.94	11.60	14.85	11.83	6.50	7.19	12.53	0.93	9.28
hm	6.60	4.48	4.48	—	—	—	—	—	1.98	—	1.76
il	—	4.71	5.02	0.30	—	1.52	9.88	9.88	—	5.78	4.71
ap	2.50	1.68	0.67	2.35	—	3.36	0.33	0.67	1.34	0.34	0.67

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3. Rhyolite. I.3(4).1.3. (5231). Ta'iz. Analyst : Geoch. Labr. London.
4. Rhyolite. II.3.2.3. Hadjeilah (Roman, 1926, p. 233).
5. Comendite. II.4.1.3. San'aa. Analyst : I. Copuzeanu (Soda-trachyte of Roman, p. 244).
6. Soda-trachyte. I.4.1.3.'' Ta'iz (5264). Analyst : Geochem. Lab. London.
7. Quartz soda-trachyte. I''.4.(1)2.4. Ta'iz (5258). Analyst : Chem. Dept. Lab. Cairo.
8. Anorthoclase soda-trachyte. I.4.1.3(4). Ta'iz (5209). Analyst : Geochem. Lab. London.
9. Trachyandesite. II.5.1.4. Manakha. Analyst : N. Matta (Roman, 1926, p. 251).
10. Trachyandesite II.4.2.3. Manakha. Analyst : N. Matta (Plagitrachyte of Roman, 1926, p. 246).
11. Basalt with no appreciable pyroxene or olivine. II.5.3''.4''. (5292). Ta'iz. Analyst : Geochem. Lab. London.
12. Basalt. II.5.3.4. Ta'iz (5310). Analyst : Chem. Dept. Lab. Cairo.
13. Normal Basalt. II.4.4.3. Wessil. Analyst : N. Matta (trachyandesite of Roman, p. 25).
14. Trachydolerite. II.5.3.4. 'Ubal. Analyst : I. Copuzeanu (Roman, 1926, p. 262).
15. Trachydolerite. III.3.2.4. San'aa. Analyst : N. Matta (Roman, 1926, p. 267).
16. Normal Basalt. III.5.3''.4.'' Heis (5469). Analyst : Chem. Dept. Lab. Cairo.
17. Olivine basalt. II.''5.3(4).''5. Ta'iz (5307). Analyst : Chem. Dept. Lab. Cairo.
18. Ankaramitic basalt. (IVI.2.4.3(4). San'aa (trachydolerite of Roman, p. 268).
19. Ankaramitic basalt. (III) IV.1(2).'2.(2)3. San'aa (5553). Analyst : Chem. Dept. Lab. Cairo.
20. Ankaramitic basalt. III(IV).5.4.''4. Mafhaq (5795). Analyst : Geochem. Lab. London.

IV. Summary and Conclusions

The petrography of two series of volcanic rocks of Yaman was studied :

1. The Tertiary volcanics forming the high plateau and consist of stratified trapp series overlying the Nubian sandstone, and 2. the Pleistocene volcanics forming central cones to the N.W. of San'aa.

The Tertiary volcanic rocks represent a series varying in composition from the most acid comendites and rhyolites to the most basic ankaramites, the following types were examined : Riebeckite-comendite, aegyrine-kataphorite pantellerite, hololeucocratic alkaline rhyolite, riebeckite-trachyte, anorthoclase-soda trachyte, hololeucocratic tachyte, leucocratic trachyandesite, biotite-hornblende trachyandesite, leucocratic basalt (related to trachybasalt), normal basalt, olivine-basalt and ankaramite.

The Pleistocene volcanic rocks are mostly of olivine basalts with few examples of olivine-trachybasalts, and differ from the corresponding Tertiary volcanics in having a fayalitic olivine (with about 40 % Fe_2SiO_4) instead of a forsteritic one in the latter rocks (with less than 20 % Fe_2SiO_4). The olivine becomes more fayalitic towards the acid end of the suite (containing 52 % Fe_2SiO_4 in olivine trachybasalts).

The Tertiary volcanics in Yaman form an alkaline province that is comparable in many ways with those in neighbouring countries in East Africa and especially with volcanics of 'Aden (Manasse, 1908, and Shukri and Basta). Some aspects of this similarity has been already referred to. Such similarity could be further emphasised by a comparison of the comendites of Kenya (Smith, 1930, p. 219), the basalts, ankaramites of Somaliland (Lacroix, 1923, p. 273) and their associated comendites, pantellerites and sodatrachytes (Lacroix, 1930, pp. 92-97) with the corresponding rocks of Yaman described in the present work. The grorudites and anorthoclase-riebeckite trachytes described by Prior (1900 A, p. 262 and 1900 B, pp. 93-94) from the Abyssinian Plateau are very much related to the Yaman rocks. Furthermore, there is a striking analogy between the alkaline types of rhyolites and trachytes as well as the non-felspathoidal basalts and ankaramites of Madagascar (Lacroix, 1923, pp. 9 and 23), and the Yaman volcanics. The Tertiary province

in Yaman is, as a matter of fact, an example of the volcanic associations of nonorogenic continental regions that show alkaline affinities (Turner and Verhoogen, 1951, p. 141).

On the other hand the Yaman volcanics show characters of their own. They differ from the association in Kenya (Smith, 1930, and Shackleton, 1946) in being devoid of felspathoidal rocks. Phonolites and basanites recorded from Kenya are absent in Yaman, though nepheline syenites are known to occur. Again, the volcanics in Madagascar (Lacroix, 1923) include phonolitic trachytes carrying nepheline that are absent in Yaman. Roman (1926, p. 295) states that the Yaman rhyolites differ from those in East Africa in being hololeucocratic. This is incorrect as it is shown in the present work that commendites rich in soda pyroxenes and soda amphiboles occur in Yaman.

The available chemical analyses of the Tertiary association of Yaman are given in Table VII. Comparing the analyses of the Yaman basalts and their average with the olivine basalt and tholeiite magma types (Daly 1933, Edwards 1938, p. 313, Tilley 1950, pp. 38-39 and Table VIII) it is evident that its magma is related to the olivine basalt type. This is in agreement with the modes of the rocks which are devoid of pigeonites and other pyroxenes with small optic axial angles. The Yaman magma is, however, much richer in alkalies especially in soda and is noticeably poorer in magnesia.

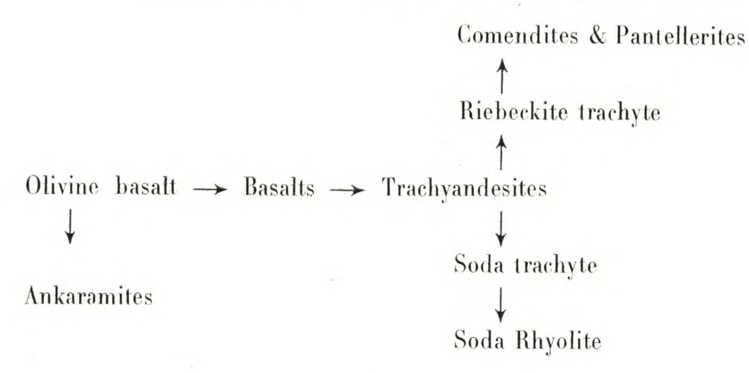
Table VIII

	Yaman magma type	Olivine-basalt magma type	Tholeiitic magma type
SiO_2	45.5	45	50
Al_2O_3	14.7	15	13
Total Iron	13	13	13
MgO	3.6	8	5
CaO	9.3	9	10
Na_2O	4	2.5	2.8
K_2O	1.4	0.5	1.2

Variation diagrams, triangular diagrams of normative Or + SiO_2 : Ab : An + Femics, of $K_2O + Na_2O$: CaO : MgO, and of Or : Ab : An were

constructed from the data available in Table VII. Though the number of analyses are few and some of them are not of a first class order yet they showed that there is a tendency for a linear variation amongst them. The $K_2O + Na_2O$: CaO : MgO is comparable to that given by Edwards (1938, fig. 13, p. 310) and shows deprivation of magnesia in the early stages of crystallization followed by a rapid depletion of the magma in both magnesia and lime. The normative Or : Ab : An triangular diagram showed very clearly the sodic nature of the rocks.

Our present knowledge of the Yaman volcanics are not sufficient to elucidate their petrogenesis. Field and laboratory evidence available at present, however, points to their production by crystallization differentiation from one parental magma. The relation between the different types of rocks suggests that their line of descent is possibly as follows :



There is no evidence available at present either in the field or in slides for the assimilation of limestone by the magma causing its depletion in silica and alumina relative to the alkalies.

The explanation put forward (Edwards, 1938, p. 314 and Turner and Verhoogen 1951, p. 154) that alkaline volcanic associations is related to the type of regional tectonics of a province (whether oceanic or continental) applies to the volcanics of Yaman where tension is dominant (normal faulting) and the volcanics are not genetically related to orogens.

Edwards (1930, p. 312) adopted Kennedy's theory to explain the mode of origin of the alkaline rocks of Central Victoria. The thesis of Kennedy seems, however, to be inapplicable to the alkaline rocks of Yaman as it cannot explain the presence of the alkaline acid rocks (comendites and pantellerites) in association with an olivine-basalt magma type. The trend of differentiation in Yaman did not stop at the trachyte stage but reached the acid end. Mention was made of the absence of phonolites in Yaman and their presence in some of the neighbouring provinces. In some cases either phonolites or comendites are present, while in other cases both are present together. It is interesting to study the physico-chemical conditions that govern these different trends.

Acknowledgments

The authors wish to express their gratitude to the Government of Yaman for facilities given to the first author during the expedition. We are also indebted to the authorities of Cairo University for defraying the cost of the chemical analyses.

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Fig. 1.—Wady el-Kharid in Jurassic limestone.



Fig. 2.—Alkaline syenite porphyry dyke about 7 m. thick and over 8 kms. long cutting lava series that overlie Nubian Sandstone at Hudjariah.

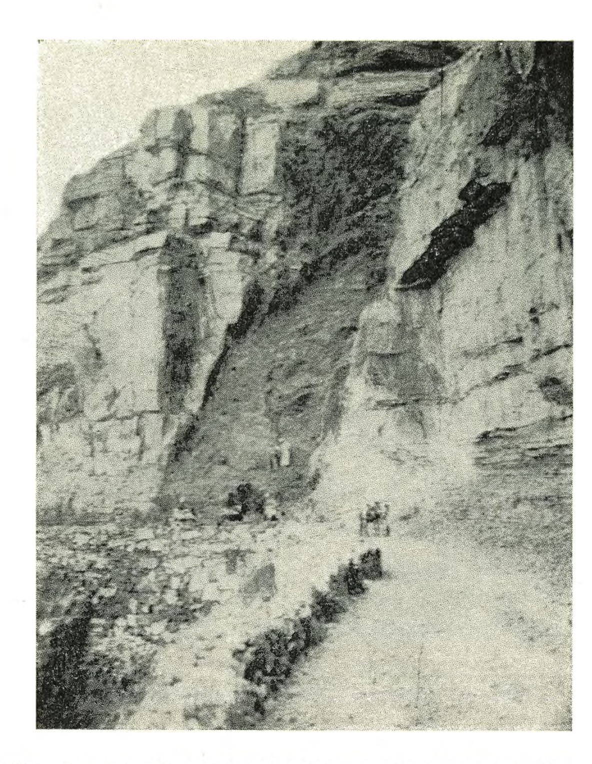


Fig. 3.—Basaltic dyke cutting Jurassic limestone at Kuhlan.



Fig. 4.—Wady Adem, showing two basaltic sills cutting Nubian Sandstone that overlies basement rocks.



Fig. 5.—Wady Adem, showing Nubian Sandstone overlying peneplaned surface of basement rocks (gabbros) and cut by basaltic dykes.



Fig. 6.—Looking S. W. from Beit el Mahdi showing Tertiary volcanics. Dj. Masswar formed of Nubian Sandstone overlying foundation rocks is in background.



Fig. 7.—Dj. Dubas showing bedded volcanic series overlying Nubian Sandstone.



Fig. 8.—Wessil showing artificial terraces on volcanics.



Fig. 9.—Looking east from a point north of el Haifa, showing Pleistocene lavas covering plain. Jurassic sediments are shown to the right.

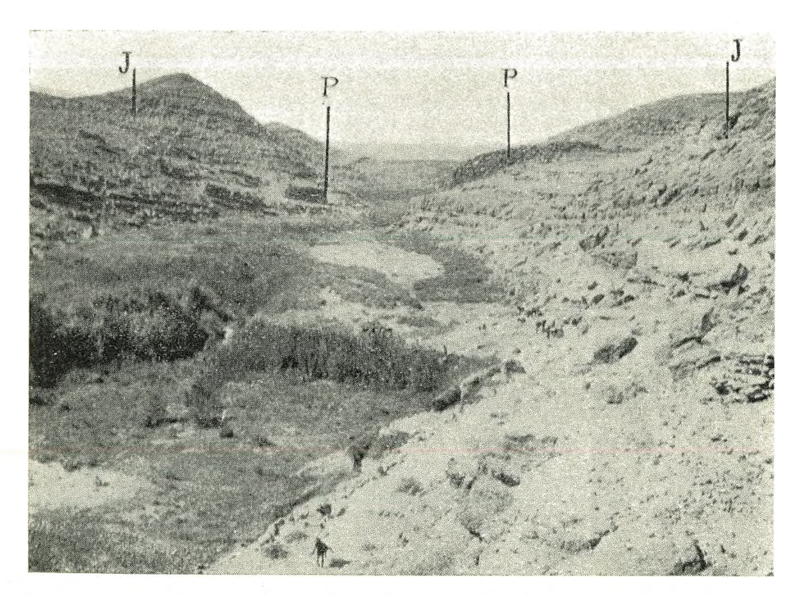


Fig. 10.—Wady el-Kharid showing Pleistocene basalt flow (P) filling a valley in Jurassic limestone (J) but is itself cut during a later pluvial period.



Fig. 11.—Ash and lava Pleistocene cone of Kaulet Kodam in Belad Hamdan.



Fig. 12.—Pleistocene basaltic cone of Kaulet-el-Erg.
Photo taken from top of Dj. Haid el Ahmer looking N.N.E.



Fig. 13.—Spherulitic riebeckite comendite (5202) from Ta'iz (Tertiary volcanics). Crossed nicols × 60.

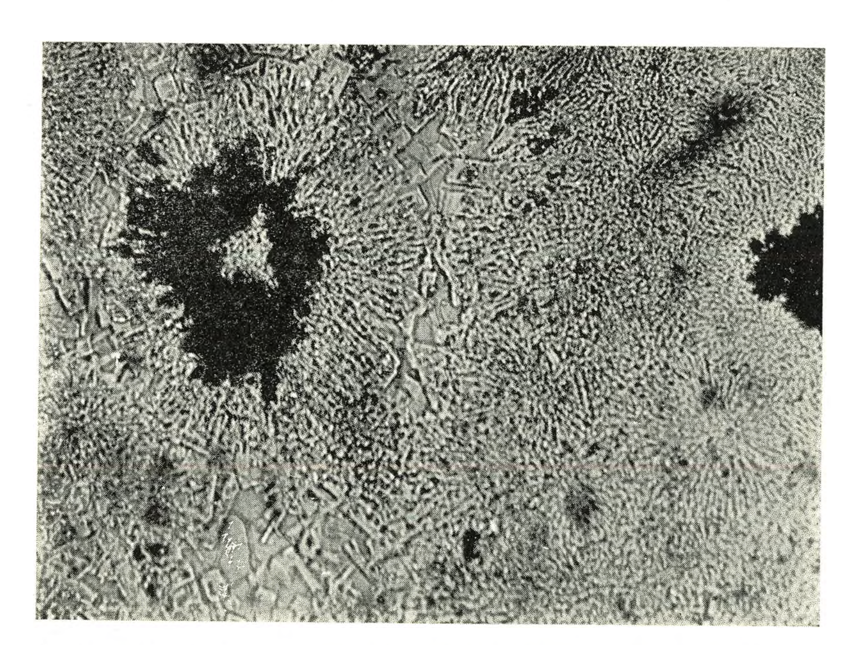


Fig. 14.—Same as fig. 13, showing riebeckite near center. Ordinary light × 100.

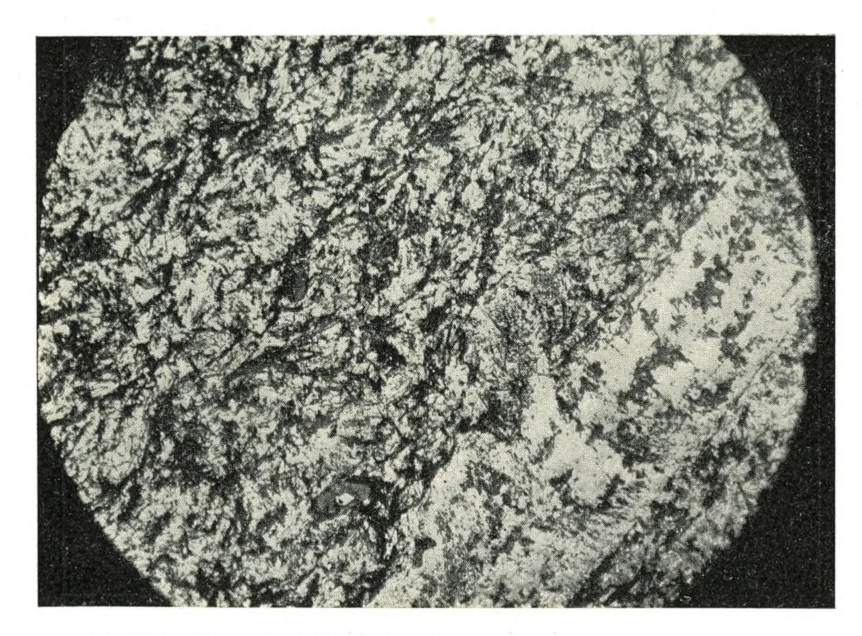


Fig. 15.—Grorudite (5470), boulder from Heis. Ordinary light × 20.



Fig. 16.—As fig. 15, showing aegyrine crystals. Ordinary light × 100.



Fig. 17.—Myrmekite-like intergrowth of quartz and felspar in a granophyric rhyolite (5236), Ta'iz, Tertiary volcanics. Crossed nicols × 32.

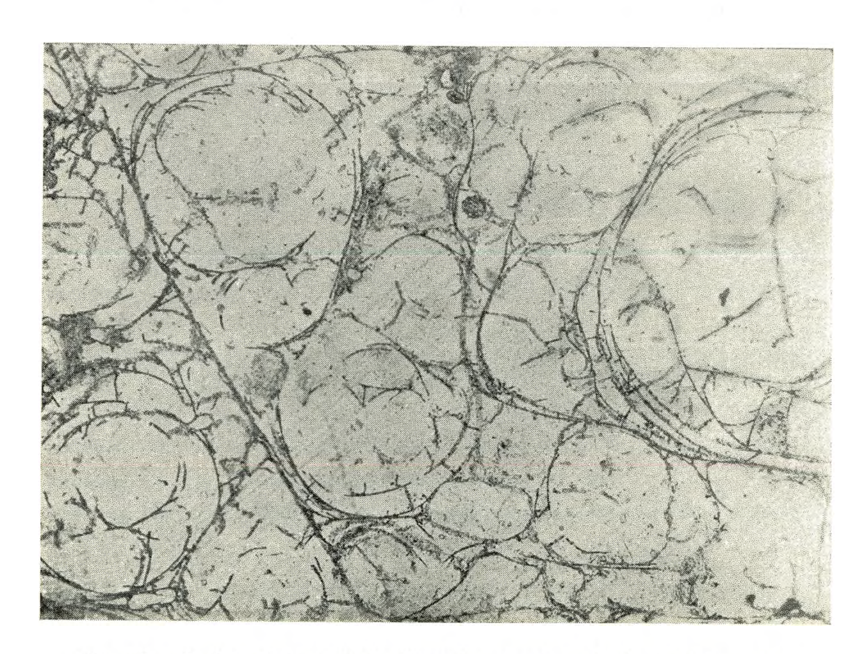


Fig. 18.—Perlite (5279), Ta'iz, Tertiary volcanics. Ordinary light × 32.

Pl. X



Fig. 19.—Porphyritic basalt (5469), Heis, Tertiary volcanics. Crossed nicols × 40.



Fig. 20.—Non-porphyritic basalt (5323), Dj. Gubah, Tertiary volcanics. Ordinary light × 60.

Pl. XI

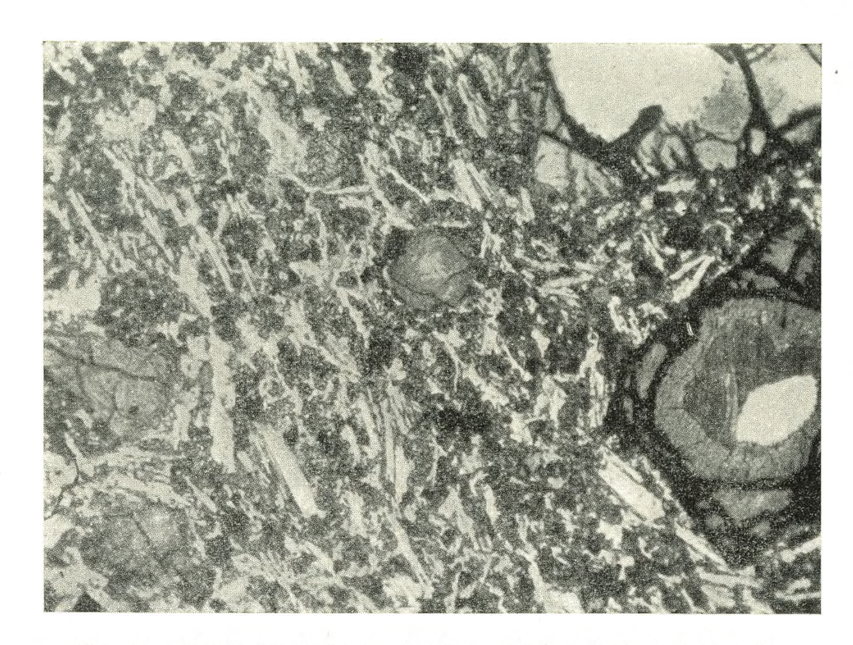


Fig. 21.—Porphyritic olivine basalt (5412), Hudjariah, Tertiary volcanics, showing altered olivine. Ordinary light × 32.



Fig. 22.—Ankaramite (5590) boulder from Hamdan, showing large phenocrysts of titaniferous augite (A). Ordinary light × 32.

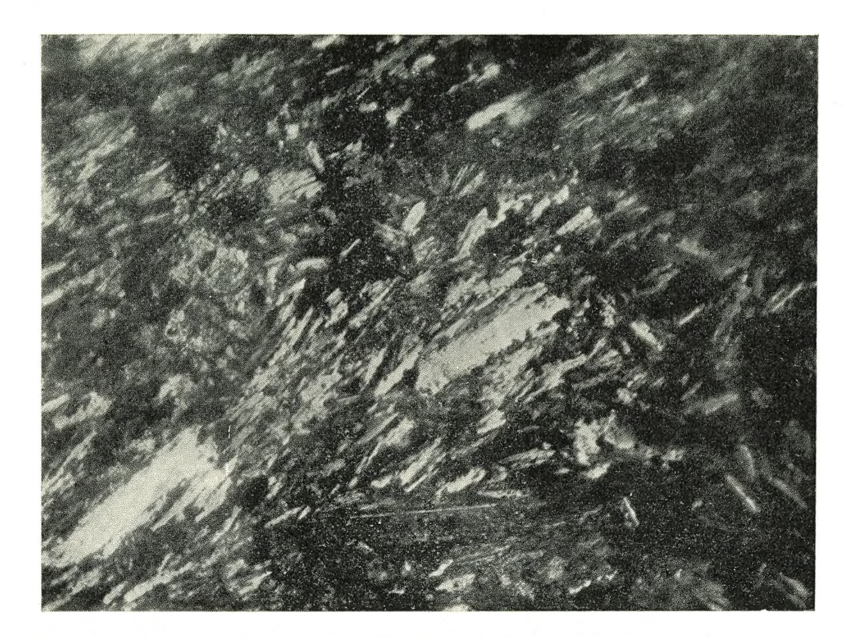
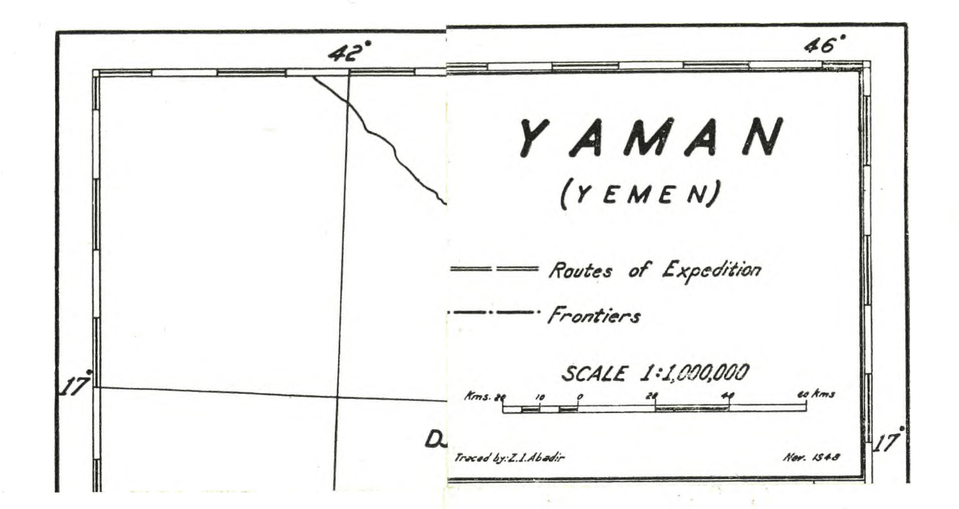
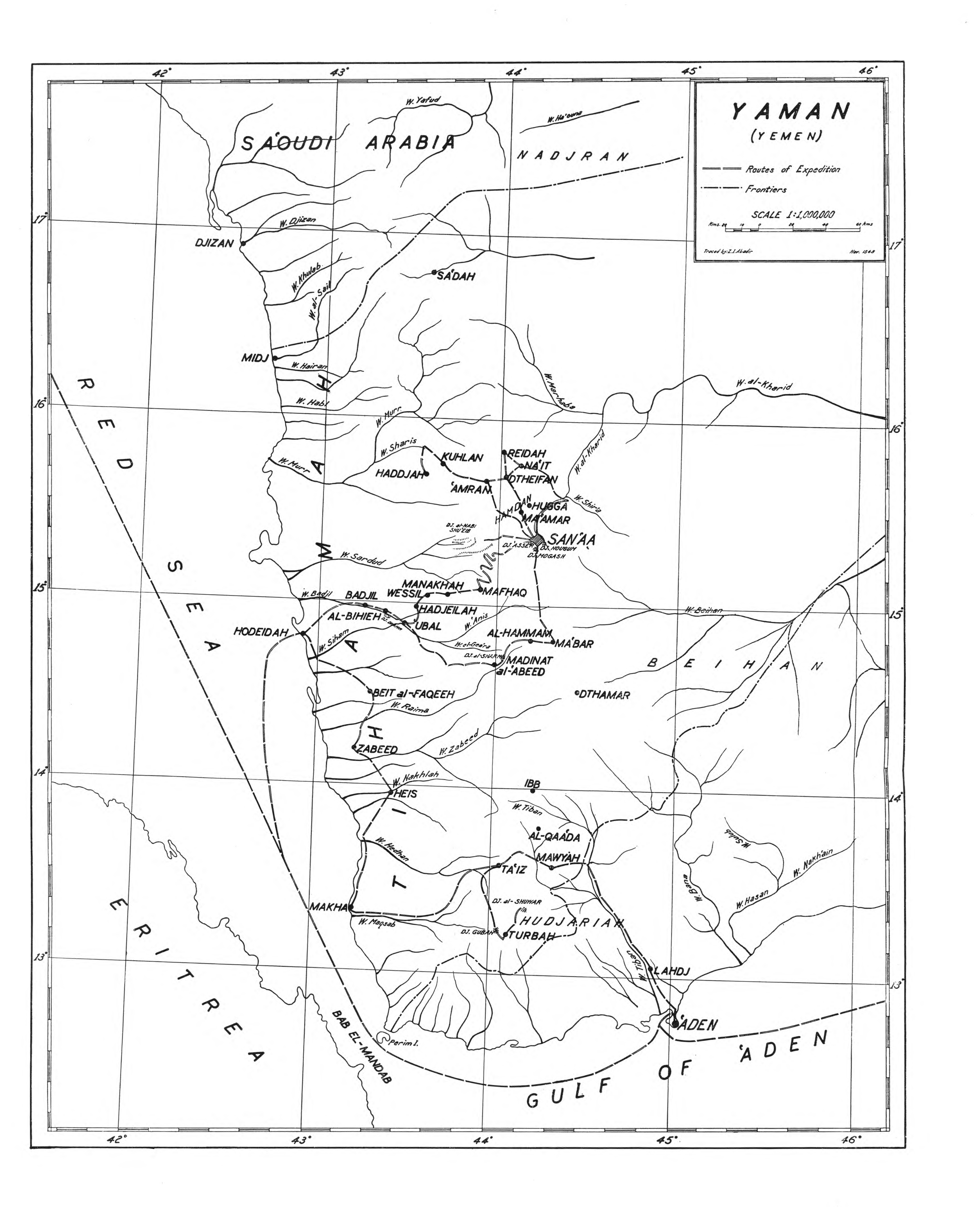


Fig. 23.—Olivine trachybasalt (5598), Pleistocene, Hamdan. Crossed nicols × 60.



Fig. 24.—Doleritic olivine basalt (5559), Pleistocene, Hamdan, showing ophitic structure. Ordinary light × 76.




YAMAN
(YEMEN)
Routes of Expedition
Frontiers
SCALE 1:1,000,000
Traced by: Z.I. Abadir
Nov. 1948
SAOUDI ARABIA
NADJRAN
W. Yafud
W. Ha'ouna
DJIZAN
W. Djizan
SA'DAH
W. Khulab
W. al-Sail
MIDJ
W. Hairan
W. Habl
W. Murr
W. Mar-haba
W. al-Kharid
W. Sharis
KUHLAN
REIDAH
NA'IT
HADDJAH
DTHEIFAN
'AMRAN
W. Shira
HAMDAN
HUGGA
MA'AMAR
SAN'AA
DJ. al-NABI SHU'EIB
DJ. 'ASSER
DJ. NOUGUM
DJ. MOGASH
W. Sardud
MANAKHAH
WESSIL
MAFHAQ
BADJIL
W. Badjil
HADJEILAH
AL-BIHIEH
UBAL
W. 'Anis
HODEIDAH
W. Siham
AL-HAMMAM
MA'BAR
W. Beihan
W. el-Gea'ra
DJ. al-SHARAQ
MADINAT al-'ABEED
BEIHAN
BEIT al-FAQEEH
DTHAMAR
W. Raima
ZABEED
W. Zabeed
W. Nakhlah
HEIS
IBB
W. Tiban
AL-QAADA
W. Sulub
W. Hedhan
TA'IZ
MAWYAH
W. Nakh'ain
W. Bana
W. Hasan
MAKHA
DJ. al-SHUWAR
HUDJARIAH
W. Maqsab
DJ. GUBAN
TURBAH
LAHDJ
W. Tiban
ADEN
Perim I.
BAB EL-MANDAB
RED SEA
ERITREA
GULF OF 'ADEN
TIHAMA

A CLASSIFICATION OF THE PYROCLASTIC ROCKS OF YAMAN (EGYPTIAN UNIVERSITY SCIENTIFIC EXPEDITION TO S. W. ARABIA)[1]

BY

N. M. SHUKRI AND E. Z. BASTA

Introduction

A big assemblage of pyroclastic rocks was collected by the first author, during the Egyptian (now Cairo) University Scientific Expedition to the south-western portion of Arabia (Huzayyin, 1936, 1937). These rocks form part of the bedded trapp series which constitute the high volcanic plateau of Yaman overlying directly the Nubian Sandstone, and belong to the Upper Cretaceous or Lower Tertiary age. They usually alternate with the lava beds of the same series which have been previously studied by the same authors (Shukri and Basta, 1954).

Roman (1926) described « comendite-tuffs » which do not contain any soda ferromagnesian minerals, trachyte tuffs and « plagitrachyte tuffs ». These were described together with their corresponding volcanic rock types of the same composition. Lamare on the other hand (1930) described two hyperalkaline rhyolitic tuffs (from Dj. Nougoum) which contained aegyrine and riebeckite, and a « rhyolitic breccia without alkaline minerals » (from Haddah). However, neither of these two authors has attempted a systematic classification of these rocks.

In the present paper a three-step classification is set out. In the first grouping, the rocks are subdivided according to the type of the volcanic

[1] Communication présentée en séance du 3 mai 1954.

material present. In the second grouping, the grain-size of the component fragments is the determining factor. Further subdivision of the tuffs was carried out based on the nature of the predominating fragments (more than 50 % by volume) whether lithic, crystal or vitric.

As regard the size-limits of the component fragments, the nomenclature and the grade-scale adopted by Blyth for pyroclastic rocks (1938, 1940) are used in the present work. The different subdivisions and names are : agglomerate (more than 32 mm.), lapilli-tuff (32 to 4 mm.), coarse tuff (4 to 0.5 mm.), fine tuff (0.5 to 0.05 mm.) and dust-tuff (less than 0.05 mm.). Measurement of the diameter of the different grains was made on suitable thin sections with the use of recording eyepiece micrometer. The proportions of the different constituents was obtained by means of the Leitz integrating stage.

PETROGRAPHY

I. Rhyolite Pyroclastics

These rhyolitic pyroclastics are very widely spread in various regions in Yaman. They occur at Ta'iz, el-Ge'ara, Dj. Mogash, and along the San'aa-Hodeidah mules road. They are subdivided into : comenditic pyroclastics and rhyolitic pyroclastics devoid of soda ferromagnesia.

a. *Comendite pyroclastics*

Of these the following types are recognised :

I. Coarse comenditic crystal-tuff. — This type (5556)[1] occurring at Dj. al-Nabi Shu'eib, carries numerous crystal fragments of dark smoky quartz and some felspar together with very few lithic fragments. Under the microscope, broken crystals of quartz and rare crystals of soda-sanidine, katophorite and aegyrine-augite are embedded in a brownish-yellow glassy paste. The quartz crystals are angular to sub-angular and are partly corroded and embayed by the matrix (pl. I, fig. 1). Katophorite

[1] Numbers refer to samples housed in the Geology Department, Faculty of Science, Giza.

occurs in small crystals of about 0.05 mm. with $\hat{ZC} = 38°$ and is pleochroic from brownish-green to smoky brown. Occasionally, few imperfect microspherulites appear in vesicles in the groundmass.

Lamare (1930, p. 77) described a rhyolitic tuff with lithophyses from Dj. Nougoum near San'aa. This type contains broken crystals of quartz, felspar and aegyrine-augite and is related to the crystal tuff described above.

II. Coarse comenditic crystal-lithic tuff. — This type occurs at el-Qa'ada (5314), in Wady el-Barh between Ta'iz and Mokha (5422) and at the top of Dj. al-Nabi Shu'eib (5555). Microscopically, the rock shows broken crystals (1.1 to 2.1 mm.) ot quartz, anorthoclase, aegyrine and sometimes katophorite together with rock fragments of about 1.8 mm. in one example (5314) and about 2.5 mm. in another (5422). The fragments are embedded in a brownish-glassy base, which contains minute crystals of riebeckite and aegyrine-augite (5314). Aegyrine is sometimes present in large fragments of about 0.8 mm. which are pleochroic from dark grass-green to paler-green and greenish-brown. Katophorite, when present (5422), occurs in euhedral crystals, with $\hat{Zc} = 36°$. In one example (5314) the lithic fragments, with the exception of one fragment of a basalt, are of a granophyric comendite. These show micrographic structure of quartz and felspar and contain numerous moss-like aggregates of riebeckite. A related rock to this tuff is a green tuff described by Lamare (1930, p. 77) from Dj. Nougoum. In another example (5422) the rock fragments represent aegyrine microgranite or syenite (accidental material) and are formed of quartz or anorthoclase and aegyrine (of about 0.9 mm.) and occasional colourless or pale-green diopside with aegyrine border. The crystal fragments form some 15 % (5314) or 34 % (5422) of the rock whereas the lithic fragments vary from 10.5 % to 14 % in the same examples respectively, the remainder being glass.

b. *Rhyolitic pyroclastics devoid of soda ferromagnesia*

Related to these pyroclastics are «comendite tuffs» described by Roman (1926, p. 238) which are devoid of alkaline metasilicates and are

therefore considered here. These rocks are widely spread in different regions in Yaman, and are classified according to grain-size into the following types :

I. Rhyolitic agglomerate. — This type (5780) occurring between San'aa and Mafhag carries large rock fragments, of about 3-4 cms., that sometimes reach up to 7 cms. embedded into a dark matrix. The fragments are of glassy rhyolites which show flow structure. The matrix is more basic and is formed of crystal fragments (0.45 mm.) of andesine, augite, biotite and magnetite together with lithic fragments (up to 1 mm.) of glassy rhyolites and andesites.

II. Rhyolitic lapilli tuff. — This type occurs at el-Ge'ara, Dj. Mogash near San'aa and at Ta'iz. It contains numerous large angular lithic fragments varying from about 5.3 mm. (5519) to about 10.6 mm. (5281) in diameter but may rarely reach more than 2 cms. The fragments are mostly of glassy rhyolites either obsidians (5548) or perlites (5519). These are often devitrified and the groundmass is usually cryptocrystalline (5547). In one example of obsidians (5548) magnetite dust is present in such a form suggesting its formation after aegyrine. Vitrophyres are also represented in the lithic fragments and occur in two varieties one consisting of phenocrysts of sanidine and oligoclase (5547) the other of sanidine, albite and pale-green diopside (5548) in a glassy base. The groundmass shows flow structure (5548) and contains few imperfect microspherulites (5547). Scarce non-glassy rhyolite fragments are present (5281). These consist of quartz and anorthoclase crystals in a microcrystalline groundmass. Besides these dominant fragments of rhyolite a few smaller andesite fragments are sometimes present. They contain minute laths of oligoclase-andesine showing subparallel arrangement and numerous interstitial grains of chlorite which are probably pseudomorphs after pyroxene. The paste into which these lithic fragments are embedded is usually glassy containing few small angular fragments of quartz, sanidine, or albite.

III. Coarse rhyolitic tuffs. — These contain fragments of a diameter varying from 0.5-4 mms. They are classified according to the relative

frequencies of the lithic, crystal and vitric fragments into the following groups :

a. *Coarse rhyolitic crystal tuffs :* They are widely spread (Ta'iz, el-Ge'ara Manakhah and Mafhaq) and in thin sections they show crystal fragments, varying from about 1 mm. (5247) to 2.6 mm. (5514), with a common size of about 1.6 mm., embedded in a glassy base, which is sometimes cryptocrystalline (5247). The crystal fragments are formed of quartz and sanidine, occasionally showing micrographic intergrowths (5247). Fragments of anorthoclase microperthite, decomposed albite or pale-green diopside (5814) are occasionally present. Imperfect microspherulites rarely occur in the groundmass (5867). Besides these crystal fragments a few lithic fragments of rhyolite showing microcrystalline to cryptocrystalline groundmass (5867) or rarely of trachyte (5839) showing a base of felspar microlites with a trachytic texture are present. A « comendite-tuff » described by Roman from Manakhah (1926, p. 238) is related to the crystal tuffs already described.

b. *Coarse rhyolitic crystal-lithic or lithic-crystal tuffs :* This type occurs in southern, western and central Yaman. It consists of lithic and crystal fragments in about the same relative abundance. The lithic fragments are represented by rhyolites varying in size between 0.8 mm. (5239) and 2.65 mm. (5271) but may occasionally reach up to about 1 cm. in diameter (5273). The fragments of rhyolite consist of phenocrysts of quartz and sanidine or anorthoclase in a microcrystalline to cryptocrystalline groundmass which is sometimes spherulitic (5304). These fragments of rhyolite are occasionally glassy, often somewhat devitrified and are represented by devitrified obsidian (5271) or devitrified perlites (5786). Vitrophyres are also occasionally present (5892). Few trachytic fragments are sometimes present, and show phenocrysts of anorthoclase in a groundmass of potash felspar laths showing a trachytic structure (5304). The crystal fragments are about 1.52 mm. in diameter and consist of angular and corroded quartz, few broken sanidine crystals and occasional orthoclase microperthite or albite (5242). The lithic and crystal fragments are embedded in a glassy paste which sometimes shows flow structure.

Roman (1926, p. 238) and Lamare (1930, p. 77) described tuffs, which seem to be related to the crystal-lithic tuffs described in the present work.

c. *Coarse rhyolitic lithic tuff* : Microscopically, this type consists of large lithic fragments of about 3.2 mm. in diameter that rarely reach up to 1 cm. embedded in a glassy matrix, which contains few fragments of quartz and sanidine crystals. The lithic fragments are formed of rhyolites showing vitrophyric structure (vitrophyres) consisting of phenocrysts of quartz and sanidine of about 0.5 mm. in a glassy groundmass which shows perfect flow structure. Roman (1926, p. 238) described a « comendite» tuff from San'aa, with glassy fragments and spherulitic rhyolites carrying albite, which could be described as a rhyolitic lithic-vitric tuff.

d. *Coarse rhyolitic crystal-vitric tuffs* : These tuffs consist of numerous crystal-and less abundant vitric-fragments in a glassy base. Quantitative measurements gave 32.6 % crystal fragments and 23.9 % vitric fragments in one example (5515) and 16.2 % crystal fragments and 14.1% vitric fragments in another (5527). The crystal fragments are of angular, clear and corroded quartz and of broken crystals of sanidine or anorthoclase (5526). Fragments of albite or oligoclase, diopside and titaniferous augite are occasionally present (5787). The fragments of glass are about 1.6 mms. in diameter. They show perlitic (5526) or flow structures (5228) or they are occasionally highly vesicular (5527). Besides these crystal and vitric fragments a few lithic fragments are occasionally present. These are of rhyolites (vitrophyres) carrying phenocrysts of sanidine (5787) and occasional andesites consisting of acid plagioclase laths and magnetite grains and showing a pilotaxitic texture (5228) or a hyalopilitic base (5515). The fragments are embedded in a glassy matrix, which usually shows a flow structure. Occasionally, the matrix shows an « ash-structure» formed of shreds of brownish or colourless glass with concave outlines resulting from the breaking up of pumaceous or highly vesicular glassy lava (5526). Roman described a « comendite» tuff from Hadjeilah (1926, p. 238) which is similar to the crystal-vitric tuffs described.

e. *Coarse rhyolitic vitric-crystal tuff* : This type of tuff occurs in situ at Ta'iz (5204) and as a boulder at Haiss (5484). The rock is greyish white (5204) or pale green (5484) in colour. The vitric fragments are more abundant than the crystal fragments. They vary in size between 0.7 and 2.6 mms. in diameter. The crystal fragments are of quartz or sanidine of about 1.6 mms. The fragments are present in a glassy matrix in which chloritic matter occurs (5204). The base shows an ash-structure in one example (5484) due to the presence of angular and concave shreds of glass (pl. I, fig. 2).

IV. Fine rhyolitic tuffs. — These tuffs contain components of a diameter varying between 0.5 mms. and 0.05 mms. The following types, based on the type of fragments present, are recorded :

a. *Fine rhyolitic crystal tuff* : This type occurs at Ta'iz (5303) and at el-Ge'ara, east of 'Obal (5522). It consists of crystal fragments in a glassy base, which occasionally shows flow-structure. The crystal fragments are of minute angular quartz, rare sanidine and anorthoclase (5522) of a common size ranging between 0.2 and 0.4 mm. in diameter (pl. II, fig. 3). Beside the crystal fragments, scarce lithic fragments (andesitic or basaltic lava with a hyalopilitic structure) occur.

b. *Fine rhyolitic vitric-crystal tuff* : This fine tuff occurring in Dj. Mogash is felsitic, grey in colour and consists of both vitric and crystal fragments in a glassy base. The fragments range from about 0.32 mm. (5530) to about 0.48 mm. (5550) in diameter. The vitric fragments are in greater abundance than the crystal fragments which consist of small angular anorthoclase, quartz and less abundant diopside.

c. *Fine rhyolitic vitric tuff* : This type occurs at el-Qa'ada (5315) and it carries numerous small angular fragments and shreds of glass of about 0.4 mm. in diameter in a glassy base, which shows imperfect flow-structure. Scarce crystals of quartz and orthoclase are occasionally present.

II. Trachyte Pyroclastics

Roman (1926, p. 247) described two trachytic tuffs from the region of Wessil and a « plagitrachyte-tuff» from Manakhah. In the present work the following trachytic pyroclastics were found :

a. *Trachytic lapilli tuff.*

This type occurring at Dj. Mogash (5541-5543) carries large angular rock fragments (about 1-2 cms. in diameter) of glassy trachytes containing few minute microlites of albite or orthoclase with parallel arrangement in brown glass stained with haematite. Some fragments are pumiceous and show numerous vesicles which are elongated in the direction of flow. The matrix is formed nearly completely of green chloritic matter which occasionally contains little quartz.

b. *Coarse trachytic lithic-crystal tuff.*

This occurs at Dj. Saber at Ta'iz and carries angular rock-fragments of trachyte (about 3.2 mm. in diameter) formed of laths of sanidine and albite showing trachytic texture. These trachytic fragments seem to be alkaline as they contain patches of magnetite or chlorite that appear to be alteration products of riebeckite. Very few andesitic rock-fragments are also found. The crystal fragments are formed of anorthoclase or albite and form 17 % of the rock, the lithic fragments forming 32 % (5290).

c. *Coarse trachytic crystal-lithic tuff.*

This is similar to the previous type, except that it contains a larger proportion of the crystal fragments (about 2.1 mm.). Sometimes dark brown flakes of biotite are present (5320). Quantitative measurements on one example (5294) gave the following results :

Crystal fragments	28.6 %
Lithic fragments	14.4 %

The remainder is the matrix which is either trachytic (5294) or glassy (5320).

III. Andesite Pyroclastics

Andesitic tuffs were not described before by Roman or Lamare. All of them are coarse tuffs and are classified according to the kind of fragments into the following types :

a. *Coarse andesitic lithic tuff.*

This rock occurring at Hudjariah (5403) consists of numerous large fragments of andesite (plate II fig. 4) of about 2.6 mm. which are formed of laths of oligoclase-andesine with interstitial grains of magnetite, showing pilotaxitic or hyalopilitic texture; in the latter case, the felspar microlites are embedded in a dark-brown glass. Few of the lithic fragments are formed of trachyte consisting of laths of sanidine, sometimes with little interstitial quartz, showing typical trachytic structure. Beside these rock fragments a few crystal fragments are present.

b. *Coarse andesitic lithic-crystal tuff.*

It occurs in southern Yaman at Hudjariah and carries fragments of andesite (1.6 mms.) consisting of laths of andesine—with occasional interstitial grains of diopsidic augite—which show fluidal arrangement. Some of the andesite fragments are glassy and contain few microlites of plagioclase in a dark brown glass and occasional large porphyritic crystals of andesine (38 % An.). The crystal fragments (0.4 mms.) are largely of andesine together with pale green diopsidic augite. A mode of this type (5404) gave :

Lithic fragments	27.2 %
Crystal fragments	18 %

The rest is a glassy paste rich in haematite.

c. *Coarse andesitic crystal-lithic tuff.*

This type occurring between San'aa and Mafhag contains larger proportions of crystal fragments of about 1 mm. in diameter. These comprise andesine, few crystals of anorthoclase, green diopside and occasionally aegyrine-augite. The lithic part is formed of a few fragments of

pyroxene-andesite (2 mm. in diameter) which consist of stout laths of andesine, diopsidic-augite and magnetite and showing pilotaxitic to hyalopilitic structure. A mode of one example (5781) gave :

Crystal fragments	18 %
Lithic fragments	7 %

embedded into a yellowish-brown glassy matrix which shows flow-structure.

d) *Coarse andesitic crystal-vitric tuff.*

This type from Mafhag is similar to the previous type but contains vitric instead of lithic fragments. The vitric fragments (2.3 mm.) contain occasional chlorite in the glassy matrix which sometimes exhibits flow structure. The crystal fragments form 29 % of the rock whereas the vitric fragments form 14 % (5792).

Summary and Conclusions

The paper gives the results of a microscopical study of the pyroclastic rocks collected by the first author during the Egyptian (now Cairo) University Scientific Expedition to Yaman. These rocks form part of the bedded trapp series which constitute the high plateau of Yaman. A systematic classification was carried out based on : 1) the type of the volcanic material present, 2) the grain size of the component fragments, and 3) the nature of the predominating fragments whether lithic, vitric or crystal.

It was found that these pyroclastic rocks are rich in alkalies and show similar variations in mineralogical composition to those observed in the Tertiary lavas of Yaman. They are originally the products of the explosive action of the same fissure eruptions which gave rise to the bedded trapp series.

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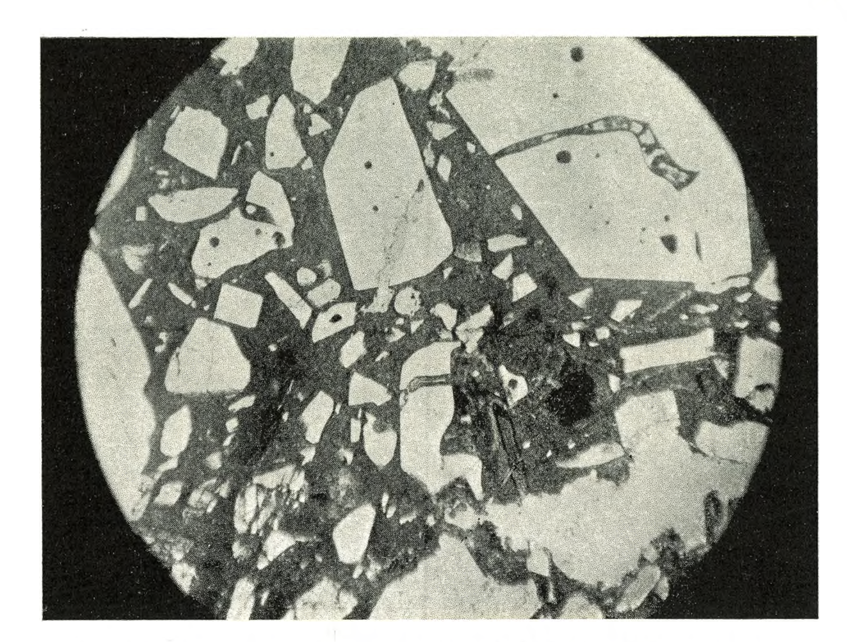


Fig. 1.—Coarse comenditic crystal tuff (5556), Dj. al-Nabi Shu'eib, Tertiary volcanics. Ordinary light (× 18).

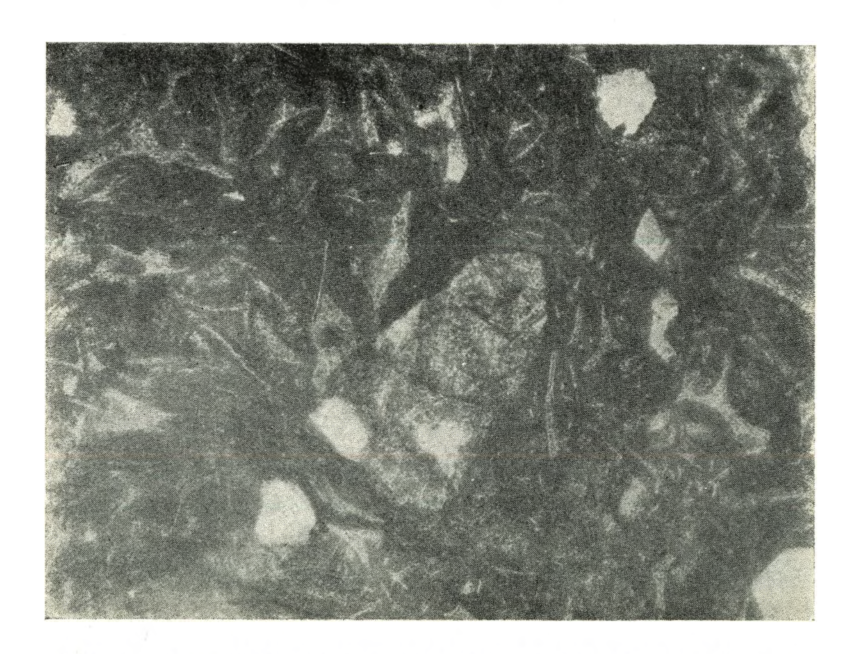


Fig. 2.—Coarse rhyolitic vitric-crystal tuff (5484), Heis, Tertiary volcanics. Ordinary light (× 18).

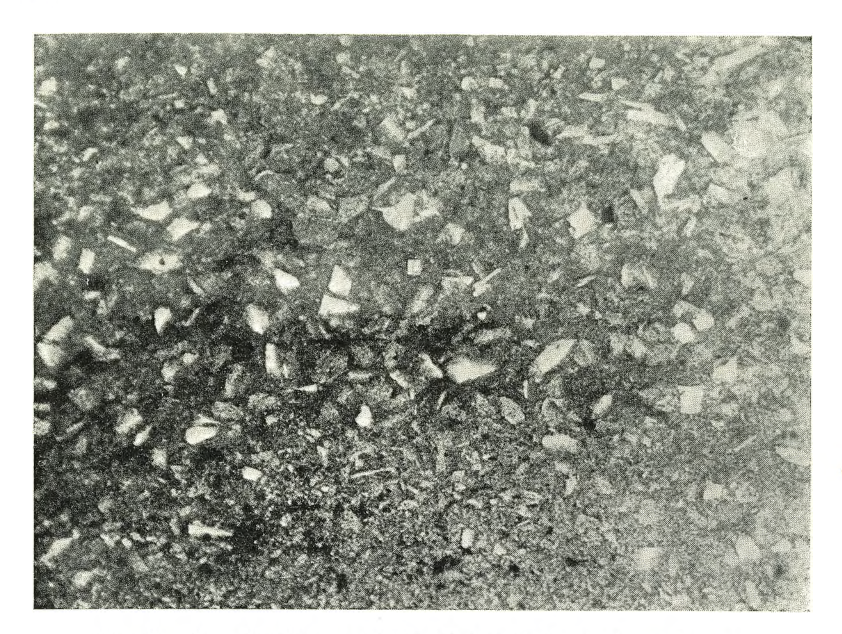


Fig. 3.—Fine rhyolitic crystal tuff (5363), Ta'iz, Tertiary volcanics. Ordinary light (× 33).

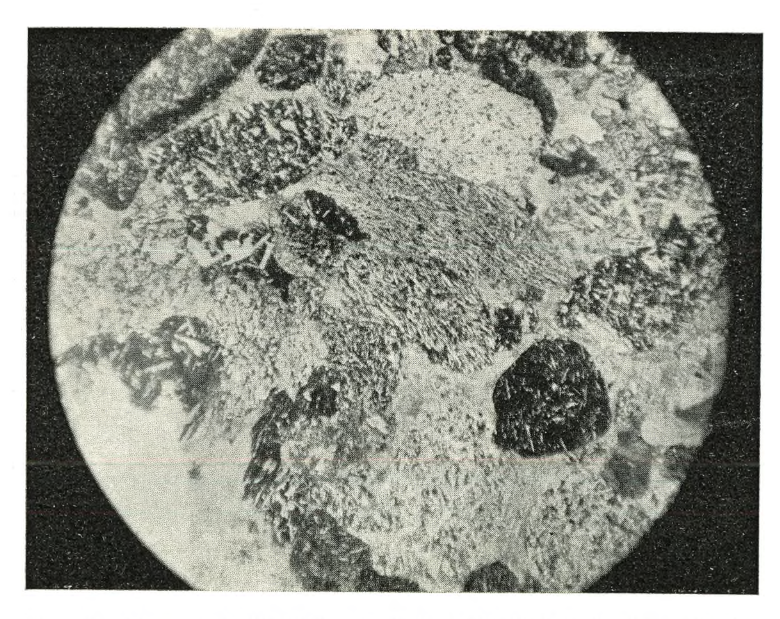


Fig. 4.—Coarse andesitic lithic tuff (5403), Hudjariah, Tertiary volcanics, showing large rock-fragments of andesite and trachyte. Ordinary light (× 18).

FACIES ANALYSIS OF THE MESOZOIC SURFACE AND SUB-SURFACE FORMATIONS OF ABU-ROASH BASED ON PERCENTAGES OF CHARACTERISTIC MICROFAUNAL FAMILIES AND GENERA[1]

BY

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I. Introduction

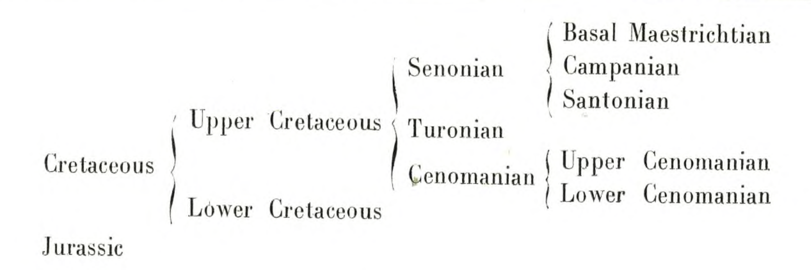
The area of Abu-Roash (also written « Abu Rauwash ») is situated on the eastern edge of the Libyan Desert abutting the Nile Valley cultivation land at the village of Abu-Roash, 8 kms. N. N. W. of the Giza Pyramids and 15 kms. due west of Cairo.

To carry out the facies analysis of the Mesozoic surface and sub-surface formations of Abu-Roash, the microfaunal content of 110 surface samples and the cores of Abu-Roash well n° 1 which was drilled by the Standard Oil Company of Egypt, was studied. The exact positions of both the surface samples and Abu-Roash well n° 1 as well as the lithological characteristics of the surface samples are indicated on charts I and II accompanying the writer's paper on the « Micro-stratigraphy of the Upper Cretaceous formations of Abu-Roash » (1954 *a*).

II. The Mesozoic stratigraphic units represented in the Area

The Middle Eocene is covering the following stratigraphic units, which were established on a microfaunal basis (the writer, 1954 *a* and *b*) :

[1] Communication présentée en séance du 19 avril 1954.



III. Facies analysis

The study of the facies conditions and facies changes during the Mesozoic in Abu-Roash was based on Tromp's circular projection method in which the percentages of the most important microfaunal families and genera on the total microfaunal association present in selected characteristic samples were computed and represented as angles in a circular projection. The representation of the data in this manner has the advantage of conveying the required information at a glance (See Chart I).

The following is a discussion of the facies analysis of each of the previously mentioned stratigraphic units :

A. *Upper Cretaceous*

1. *Senonian :*

a. Basal Maestrichtian : The sample chosen of this unit is sample n° 6. In this sample planktonic organisms form 92. 15% of the microfaunal content. This fact suggests open sea conditions and a depth not less than 900 meters. This conception is further supported by the relative scarcity of the Buliminidae, the Lagenidae, and the Rotaliidae, these last-mentioned families forming only 4.47 % of the total number of the microfauna.

b. Campanian : Samples n°s 11 and 93 were chosen as representatives for the Campanian. Also in these samples planktonic organisms are abundant, but less so than in the upper unit, forming only 62.03 % and 74.56 % of the total number of the microfauna present in samples n°s 11 and 93 respectively. Moreover, the families Buliminidae, Lagenidae, and Rotaliidae are more abundant than in the above unit, these families representing 18.07 % and 17.26 % of the total number of the microfauna in samples n°s 11 and 93 respectively. They also indicate open sea conditions, but less pronounced than in the Maestrichtian.

c. Santonian : Sample n° 88 representing the Santonian indicates shallow water conditions owing to the small number of planktonic organisms which form only 20.73 % of the microfauna present.

So, generally the Senonian is characterised by shallow water conditions passing into open sea and deeper water conditions towards the end of the epoch.

2. *Turonian :* The sample chosen to be the most representative for the Turonian is sample n° 73 in which Ostracods and echinoid spines form 47.88 % and 43.72 % respectively of the total number of the microfaunal content. Such a great abundance of Ostracods and echinoid spines indicates shallow water conditions.

3. *Cenomanian :* In the Cenomanian, shallow conditions prevail as indicated by sample n° 109 in which 45.51 % and 37.89 % of the microfauna are represented by the Trochamminidae (genus Trochammina) and the Rotaliidae (genus Rotalia) respectively.

It is usually considered that the abundance of arenaceous foraminifera is indicative of cold water conditions. The presence of such an abundance of arenaceous foraminifera in the Cenomanian, where warm shallow water conditions are known to prevail (for example lithology, presence of Rudistae, Oysters, etc.) indicates that this conception is not always correct.

B. *Lower Cretaceous*

The cores taken in the Lower Cretaceous contain no microfauna. This, in addition to the fact that the whole section consists of sandstones, allows the writer to believe that this area, which the sea was invading since the Cenomanian was dry land in the Lower Cretaceous.

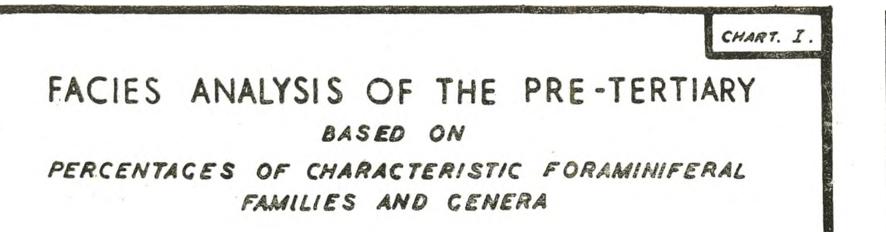
C. Jurassic

From the Jurassic two cores were chosen, namely cores n°s 80 and 69. In core n° 80, which is deeper than core n° 69, the microfaunal content is formed by the family Lituolidae (72.68 %), Ostracods (8.21 %), and echinoid spines (16.42 %). Of the 72.68 % formed by the Lituolidae, 58.66 % is formed by the genus Haplophragmoides. The microfaunal content of this core bears evidence to the shallow water and rather brackish conditions that prevailed during this part of the Jurassic. Deep water conditions then followed as is revealed by the great number of arenaceous foraminifera (79.42 %) as well as their poverty in the genera (of which only Turritellalla is present) in core n° 69.

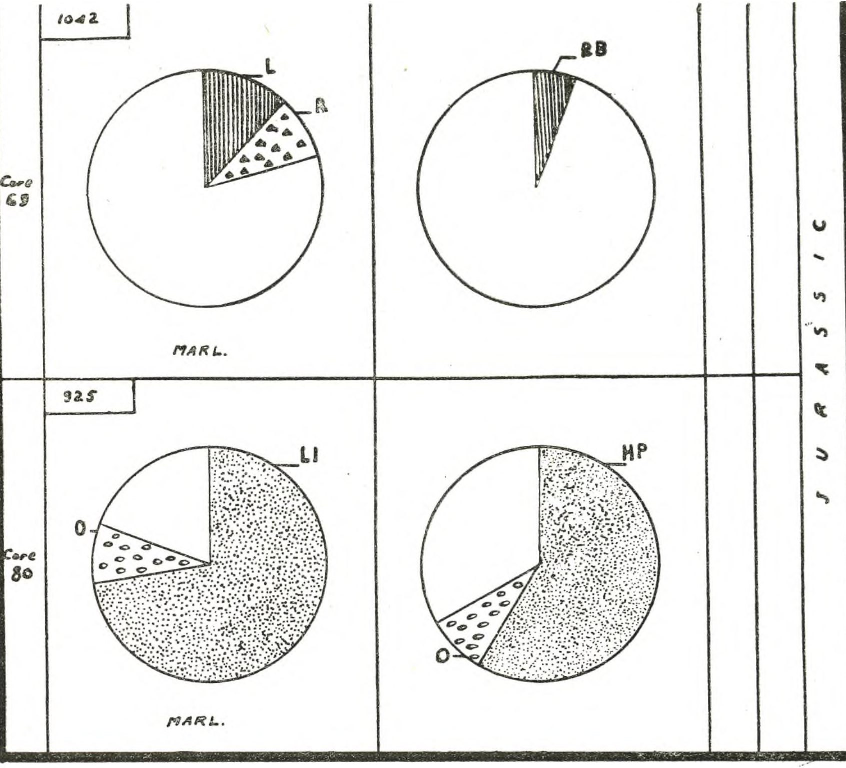
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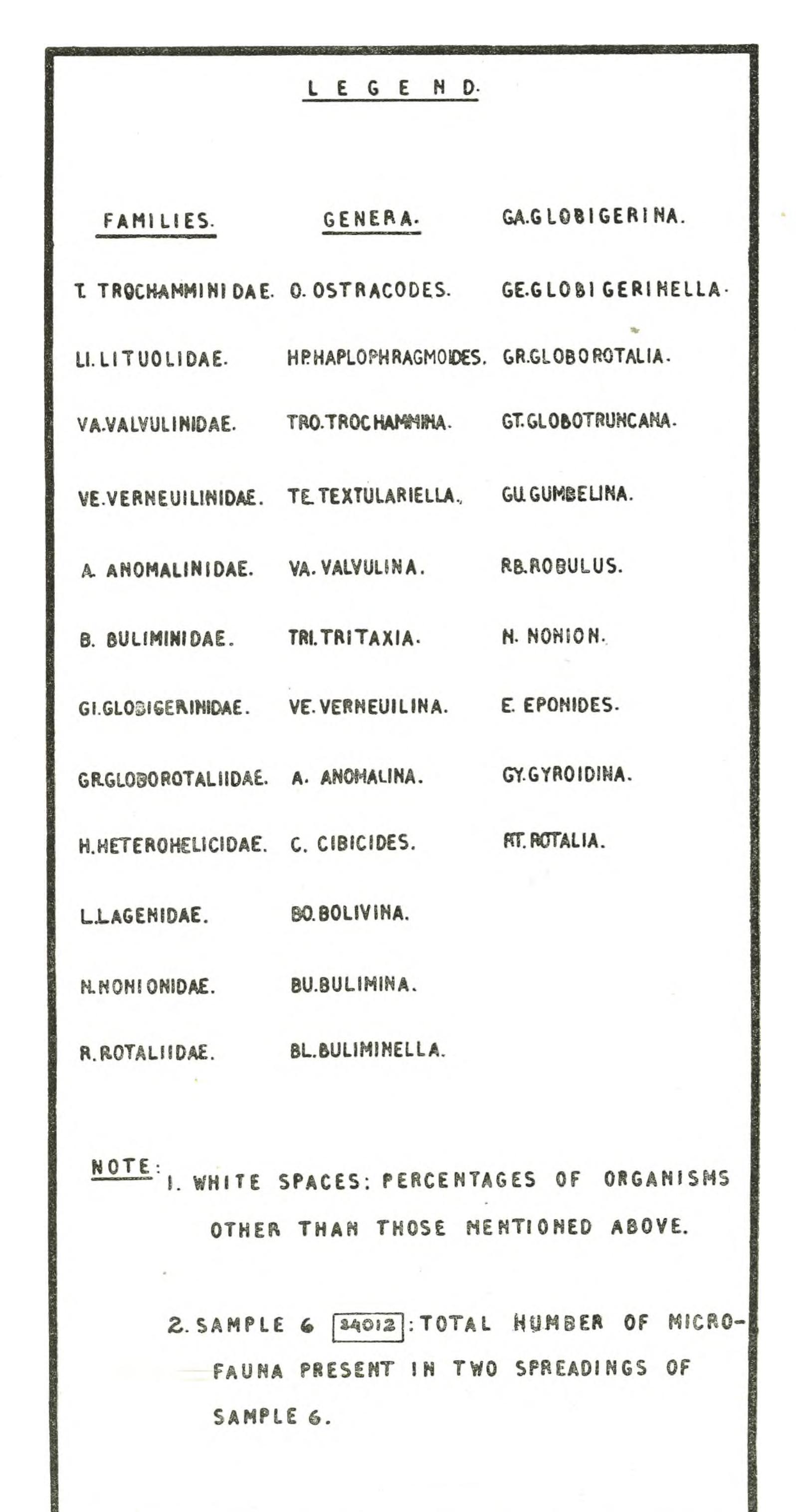
Osman, A. 1954 *a*. Micro-stratigraphy of the Upper Cretaceous surface formations of Abu-Roash, *Bulletin de l'Institut d'Egypte*, t. XXXVI, fasc. 1.

—— 1954 *b*. *The stratigraphy of the Pre-Tertiary sub-surface formations of Abu-Roash*, to be published in the near future.



SAMPLE Nr.	CHARACTERISTIC FAMILIES.	CHARACTERISTIC GENERA.	AGE.		
6	24012 — CHALKY MARLY LIMESTONE.		BASAL PART of MAESTRICHTIAN.	SENONIAN	UPPER CRETACEOUS
11	29375 — CHALKY MARLY LIMESTONE.		CAMPANIAN	SENONIAN	UPPER CRETACEOUS
93	3983 — CHALKY LIMESTONE		CAMPANIAN	SENONIAN	UPPER CRETACEOUS
88	299 — CHALKY LIMESTONE		SANTONIAN	SENONIAN	UPPER CRETACEOUS
73	238 — CHALKY LIMESTONE.		TURONIAN		UPPER CRETACEOUS
109	5156 — MARL.		CENOMANIAN		UPPER CRETACEOUS





LEGEND.

FAMILIES.	GENERA.	
T. TROCHAMMINIDAE.	O. OSTRACODES.	GA. GLOBIGERINA.
LI. LITUOLIDAE.	HP. HAPLOPHRAGMOIDES.	GE. GLOBIGERINELLA.
VA. VALVULINIDAE.	TRO. TROCHAMMINA.	GR. GLOBOROTALIA.
VE. VERNEUILINIDAE.	TE. TEXTULARIELLA.	GT. GLOBOTRUNCANA.
A. ANOMALINIDAE.	VA. VALVULINA.	GU. GUMBELINA.
B. BULIMINIDAE.	TRI. TRITAXIA.	RB. ROBULUS.
GI. GLOBIGERINIDAE.	VE. VERNEUILINA.	N. NONION.
GR. GLOBOROTALIIDAE.	A. ANOMALINA.	E. EPONIDES.
H. HETEROHELICIDAE.	C. CIBICIDES.	GY. GYROIDINA.
L. LAGENIDAE.	BO. BOLIVINA.	RT. ROTALIA.
N. NONIONIDAE.	BU. BULIMINA.	
R. ROTALIIDAE.	BL. BULIMINELLA.	

NOTE: 1. WHITE SPACES: PERCENTAGES OF ORGANISMS OTHER THAN THOSE MENTIONED ABOVE.

2. SAMPLE 6 [24012]: TOTAL NUMBER OF MICRO-FAUNA PRESENT IN TWO SPREADINGS OF SAMPLE 6.

MICRO-STRATIGRAPHY OF THE UPPER CRETACEOUS FORMATIONS OF ABU-ROASH[1]

BY

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I. Introduction

The area of Abu-Roash (also written «Abu Rauwash») lies near the edge of the Libyan Desert, ending at the Nile Valley cultivation at the village of Abu-Roash, 8 kms. N. N. W. of the Pyramids of Giza and 15 kms. due west of Cairo.

Tromp (1939, 1940 and 1951) introduced the terms macro-stratigraphy and micro-stratigraphy to denote the two subdivisions of the general science of stratigraphy, the determination of the succession of events in the earth crust during the history of the earth being based in the former subdivision on the evolution and occurrence of macrofossils and in the latter one on the occurrence and development of either heavy minerals or micro-organisms and fragments of macro-organisms which require microscopic analysis. Micro-stratigraphy is thus based on two sub-sciences, namely microscopic mineralogy and micropalaeontology. In the present study only micropalaeontological methods have been used for the establishment of the micro-stratigraphy of the area.

II. Samples and their location

110 samples were collected by Tromp and the writer during the winters of 1948 and 1949 from seven sections, the exact positions of which

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[1] Communication présentée en séance du 19 avril 1954.

are indicated on Beadnell's geological map (1902), which except for some minor structural features seems to be correct (chart I). Section I includes samples 1-3, which are of Middle Eocene age as they were crowded with *Nummulites gizehensis*. Section II contains samples 4-26. These samples were again classified into three sub-sections, namely II A, II B, and II C. Section II A contains samples n°s 10-20. Section II B is 260 ms. west of section II A and contains sample n° 21 only. Section II C contains samples n°s 4-9 and is about 180 ms. west of section II B. Samples n°s 22, 23, 24, 25 and 26 are between sections II B and II C with 5 ms. interval between each two samples, and sample n° 22 is 5 ms. west of section II B. Section III includes samples n°s 27-29 which were found to cantain no microfossils. Section IV includes samples n°s 30-63 and 96-110. Section V includes samples n°s 64-69. Section VI includes samples n°s 70-79. Section VII includes samples n°s 80-95. The numbering of these samples as indicated in the charts is in accordance with the order of collecting and has no bearing on their actual stratigraphic order.

III. Macro-stratigraphy of Abu-Roash

The macro-stratigraphy of Abu-Roash has been an interesting field of study for many geologists since the year 1835. Faris (1948) summarised very briefly all the previous geological studies of the area and tabulated at the end of his paper the classification of the horizons of the area as given by the different authors (idem., pl. III).

The macro-stratigraphy of the area was fully described by Beadnell (1902) and was verified by Tromp and the writer during their visits of the area (chart II). It can be summarised as follows :

SENONIAN....	White Chalk or Upper Chalk Series. Ostrea and Plicatula Series.
TURONIAN....	Flint Series. Acteonella-Nerinea Series. Chalky Limestone Series.
CENOMANIAN.	Rudistae Series. Clay and Sandstone Series.

As regards the ages of these series the writer agrees with Beadnell (1902), Dacqué (1903), and Faris (1948) in assigning a Cenomanian age to the oldest beds in the area. On micropalaeontological evidence, the writer quite agrees with Beadnell in considering the *Rudistae series* as of Cenomanian age, and not of Turonian age as Faris says.

The writer also agrees with Beadnell in considering the *Chalky Limestone Series,* the *Acteonella-Nerinea Series* and the *Flint Series* as belonging to the Turonian.

Santonian, Campanian, and Maestrichtian ages have been assigned to the *Ostrea and Plicatula Series* and the *Upper Chalk Series,* and not Santonian, Campanian, Maestrichtian, and Danian as Beadnell says, nor Upper Santonian as Fourtau (1899, 1900, and 1903) thinks, nor Santonian and Campanian as considered by Dacqué (1903). As to the Coniacian and Emscherian used by Faris (1948) the writer has to mention in this connection that the introduction of such terms in micropalaeontological studies without sufficient work being carried out in areas between the type localities in N. Europe and here in Egypt, is a matter which has to be approached with great caution. For this reason it is in the writer's opinion that it is safer for the present study to divide the Senonian into three units only, which may called Lower Senonian or Santonian, Middle Senonian or Campanian, and Upper Senonian or Maestrichtian.

IV. Laboratory procedure

The micropalaeontological method used in this study is "The Quantitative Generic Microfaunal Method" developed by Tromp (1939, 1940, 1941, 1942 and 1943).

For the preparation of the samples for micropalaeontological examination always 200 gms. of rock were crushed into fine powder in a bronze mortar. This was done only if the samples were not soft enough to be cooked directly. The powder was boiled for half an hour with a few spoonfuls of sodium carbonate, and after cooking it was passed through a set of sieves with meshes 0.6 mm., 0.3 mm., 0.15 mm., and 0.075 mm. The residue left on each sieve was dried and weighed and from each

residue two spreadings on the picking instrument invented by W. Scheffen (1934) were examined under a binocular microscope and the microfauna picked and put in the underlying slide through the hole in the centre of the instrument. The contents of the resulting four slides were studied generically and quantitatively and a quantitative generic microfaunal chart was prepared (chart III). If the residue of any of the four meshes was so rich in micro-organisms that it would require too much time to count the whole fauna present in two spreadings 1/8, 1/4, or 1/2 spreading was sufficient to give an accurate idea on the actual quantitative relations, but when the data obtained were to be compared or represented graphically, the number of genera present in two spreadings was computed.

As quantitative figures are difficult to appreciate at a glance in a graphic chart the following graphic symbols were used : dots for very rare (1-5), a dashed line for rare (6-10), a continuous thin line for common (11-100), a line 1 mm. in thickness for abundant (101-1000), and a 2 mm.-thick line for flooded (more than 1000).

V. Micro-stratigraphy of the Upper Cretaceous Formations of Abu-Roash

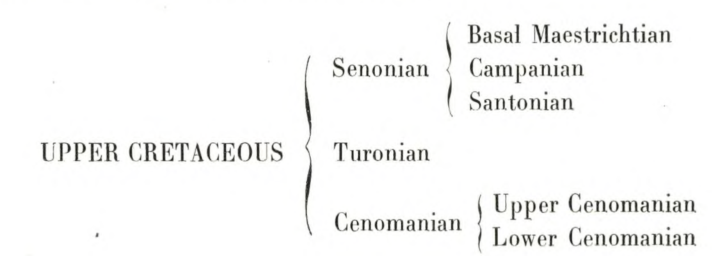
The identification of the microfauna upon which this study was based was carried out according to the latest classification of J. A. Cushman (1948).

The establishment of the age boundaries between the different units is based on the previous studies of Tromp (1940, 1941, 1942, 1943 and 1949).

A. *Main Characteristics of Established Boundaries :*

The oldest beds overlying the Cretaceous in Abu-Roash are of Middle Eocene age as is revealed by the presence of *Nummulites gizehensis* in these rocks. Although they cover a considerable part of the area, a discussion of these beds is omitted as the study of the Upper Cretaceous formations only has been the main object of this paper.

The Middle Eocene is covering the following stratigraphic units which were established on a microfaunal basis :



Evidence for Senonian Age :

The Senonian rocks are the youngest Cretaceous rocks in the area. They have a thickness of 148 ms. They are considered to be of Senonian age for the following reasons :

1. Presence of thousands of Gümbelinas, many larger than 0.3 mm.
2. Presence of Globotruncanas.
3. Presence of typical Cretaceous genera such as Pseudotextularia and Bolivinoides, together with characteristic species such as Bolivina incrassata, Gaudryina rugosa and Anomalina ammonoides.
4. Presence of Buliminas, mostly smaller than 0.2 mm.
5. Presence of numerous Valvulinidae, Verneuilinidae and Lagenidae.
6. Absence of typical Tertiary forms such as Uvigerina and Globigerinoides.

Evidence for Turonian Age :

The Senonian is underlain by a 210 ms. thick section (chart II) which on the basis of macrofossils is considered to be of Turonian age. The study of microfossils also leads to the same conclusion for the following reasons :

1. Sudden faunal drop below sample n° 83 in a continuous Upper Cretaceous section.
2. Disappearance of Valvulinidae and Verneuilinidae and relatively greater development of Trochamminidae and Lituolidae.
3. Absence of Globigerinas and Globigerinellas.
4. Absence of Heterohelicidae except one Gümbelina in sample n° 53.

Evidence for Cenomanian Age :

Below the Turonian a section of 75 ms. is developed which on microfaunal basis is considered as Cenomanian. The microfaunal association of this section does not differ fundamentally from the above mentioned Turonian section. However, the greater abundance of arenaceous foraminifera especially Lituolidae and Trochamminidae as well as nonforaminiferal micro-organisms in the lower section favours the erection of a stratigraphic boundary between both sections.

I. *Senonian Boundaries :*

The following units of the Senonian were distinguished; Basal Maestrichtian, Campanian, and Santonian.

a. The boundary between the basal part of the Maestrichtian and the Campanian : As the Upper Senonian is characterised by the dominance of Globigerinas and Globorotalias over Globigerinellas and Globotruncanas (Tromp, 1940 and 1949) the boundary between the Maestrichtian and the Campanian can be placed between samples n°s 7 and 24. The presence of some samples above sample n° 24 in which Globigerinellas and Globotruncanas are dominating over Globigerinas and Globorotalias leads the writer to consider the section overlying sample n° 24 as of Basal Maestrichtian age, where it is possible that the characteristics of both the Maestrichtian and the Campanian can co-exist.

The Maestrichtian on the whole represents a small part of the whole Senonian section, being only 2 ms. in thickness. The greatest part was probably removed as a result of the Middle Eocene erosional unconformity.

b. The boundary between the Campanian and the Santonian : This boundary lies between sample n° 92 and sample n° 91. It is placed at this level for the following reasons :

1. General drop of most of the genera below the suggested boundary, such as Dorothia, Siphogaudryina, Tritaxia, Anomalina, Cibicides, Globigerina, Globigerinella, Globorotalia, Globotruncana, Bolivinita, Gümbelina, Dentalina, Frondicularia, Robulus, Eponides, Gyroidina, and Rotalia.

2. General drop of the arenaceous foraminifera below the boundary, and while they mostly belong to the Valvulinidae and the Verneuilinidae in the Maestrichtian and the Campanian, they are mostly formed by the Trochamminidae in the Santonian.

The Campanian is the largest Senonian unit having a thickness of 53 ms., as compared with the Santonian which has a thickness of 31 ms. only.

Senonian Turonian Boundary :

This boundary lies between samples n°s 83 and 82 for the following reasons :

1. Most of the Senonian characteristics end at this boundary; Anomalina, for example, which is represented by 32 individuals in sample n° 83 which is just above the boundary, has a very rare occurrence below this boundary.

2. Globotruncana which is a characteristic Senonian genus disappears below that boundary.

II. *Turonian Boundaries :*

In an attempt to divide the Turonian by microfossils into units equivalent to the afore-mentioned macro-stratigraphic units, a graph was prepared to illustrate the relative distribution of only arenaceous foraminifera, these being the most abundant microfossils in the Turonian samples (charts III and IV). Chart IV reveals certain characteristics for each of the three Turonian units. These characteristics can serve to establish the boundaries between the three units as can be seen from the following :

1. Corresponding to the *Flint Series,* there is a unit in which the arenaceous foraminifera are few in number, ranging from 0 to 31. The distribution of the arenaceous foraminifera among the samples in this unit is rather a variable one, the samples at the bottom containing the highest number of them and those at the top either having a smaller number or containing no foraminifera at all.

2. Corresponding to the *Acteonella-Nerinea Series,* there is a unit in which the distribution of the arenaceous foraminifera among the samples is not even, *i. e.* with abrupt jumps from samples containing a

large number of foraminifera to a relatively greater number of samples containing very few or none at all. An example of these abrupt jumps is the jump from sample n° 69 with 1837 foraminifera to sample n° 68 with only 2.

3. The unit corresponding to the lowermost *Chalky Limestone Series* is characterised by the presence of very few or even no arenaceous foraminifera at all.

Turonian Cenomanian Boundary :

The Turonian is covering a section which was considered to belong to the Cenomanian owing to the large increase in the number of the arenaceous foraminifera in the lower section.

Beadnell (1902) classified the Cenomanian into two series; the *Rudistae Series* and the *Clay and Sandstone Series*. Faris (1948) considered the *Rudistae Series* as of Turonian age. The writer is rather inclined to consider the *Rudistae Series* as belonging to the Cenomanian for the following microfaunal reason :

As is clearly seen from chart IV, the Turonian is on the whole very poor in arenaceous foraminifera, while below its lowermost series, namely the *Chalky Limestone Series,* follows a section which is much richer in its arenaceous foraminiferal content. The upper part of this section, from sample n° 37 to sample n° 45, belongs to the *Rudistae Series*. The curve showing the relative distribution of the arenaceous foraminifera in the samples belonging to both Turonian and Cenomanian clearly shows that a boundary line can preferably be drawn between the lowest samples belonging to the *Chalky Limestone Series,* and the uppermost sample belonging to the *Rudistae Series,* rather than between the lowermost sample of the *Rudistae Series,* and the uppermost sample of the *Clay and Sandstone Series*.

III. *Cenomanian Boundaries :*

Considering the Cenomanian the writer was able to distinguish between an Upper Cenomanian and a Lower Cenomanian, the boundary line lying between samples n°s 100 and 99, and the Lower Cenomanian beginning from sample n° 99 till the base of the surface section.

The main differences between Upper and Lower Cenomanian as deduced from the microfaunal of the Cenomanian rocks in the area are :

1. In the Upper Cenomanian the majority of the arenaceous foraminifera belong to the families Trochamminidae and Lituolidae, while in the Lower Cenomanian it is only the Lituolidae which is the most dominant arenaceous family, Trochamminidae being either rare or very rare.

2. Ostracods are better developed in the Lower Cenomanian than in the Upper Cenomanian.

3. Calcareous foraminifera, although on the whole very rare in the Cenomanian, occur, nevertheless, more frequently in the Upper Cenomanian.

B. Microfaunal Zones :

A close study of the data compiled in chart III reveals the presence of certain microfaunal zones which may prove to be of value for regional correlation work. The following is a discussion of each of the suggested microfaunal zones :

1. *Quinqueloculina Zone :* The genus Quinqueloculina is of very rare to rare occurrence throughout chart III except in this zone where it is common to abundant. The exact level of this zone is shown in chart II. It extends from 9 ms. above to 8 ms. below the established Senonian (Santonian) Turonian boundary.

2. *Rotalia-Trochammina-Lituolidae Zone :* A close study of chart III reveals the presence of a sample (sample n° 59) in which there is quite an abundant occurrence of the genus Rotalia together with members of the two arenaceous families Trochamminidae and Lituolidae. Above this zone, the family Lituolidae is of very rare to rare to common occurrence, while the family Trochamminidae is very rare to common to abundant. It is only in this zone that the Lituolidae for the first time have an abundant occurrence while the Trochamminidae are flooded. This zone lies in the Turonian which is very poor in its calcareous foraminiferal content. In this zone, however, there is a sudden enrichment in the genus Rotalia, which is abundant while elsewhere in the Turonian it has, with the exception of one case (sample n° 66), a very rare to rare occurrence.

This zone lies at the bottom of the unit corresponding to the *Acteonella-Nerinea Series*.

3. *Trochammina Zone :* About 5 ms. below the top of the *Rudistae Series* there is a zone characterised by the fact that its foraminiferal content is formed nearly exclusively by the genus Trochammina, other foraminifera occurring in this zone being only two Ammomarginulinas. One may also call this zone the Trochammina-Ostracod zone, Ostracods being the only non-foraminiferal micro-organisms occurring in this particular zone.

4. *Rotalia-Trochammina Zone :* About 1.5 ms. below the top of the *Clay and Sandstone Series,* there is a zone characterised by the flooded occurrence of both the genera Rotalia and Trochammina. In the whole Cenomanian section, including both the *Rudistae Series* and the *Clay and Sandstone Series,* the genus Rotalia is very rare or rare except in this zone where it is flooded. Also in the Cenomanian, the genus Trochammina has nowhere a flooded occurrence except in this zone and the afore-mentioned zone n° 3.

The afore-mentioned zones are only of rather limited extent. One can also trace zones which are of a much larger extent. These latter zones are based on the relative frequencies of the different arenaceous foraminiferal families in the different stratigraphic units. The following zones are distinguished :

1. *Verneuilinidae-Valvulinidae Zone :* This zone extends from the Maestrichtian into the Campanian till approximately 3 ms. above the bottom of the Santonian.

2. *Trochamminidae-Lituolidae Zone :* Below the Verneuilidae-Valvulinidae zone there is a general shift towards the Trochamminidae and the Lituolidae families, other families being much less frequent. This zone passes through the Turonian to about 6 ms. above the bottom of the *Clay and Sandstone Series.*

3. *Lituolidae Zone :* In this zone there is a dominance of the family Lituolidae over all the other arenaceous foraminiferal families.

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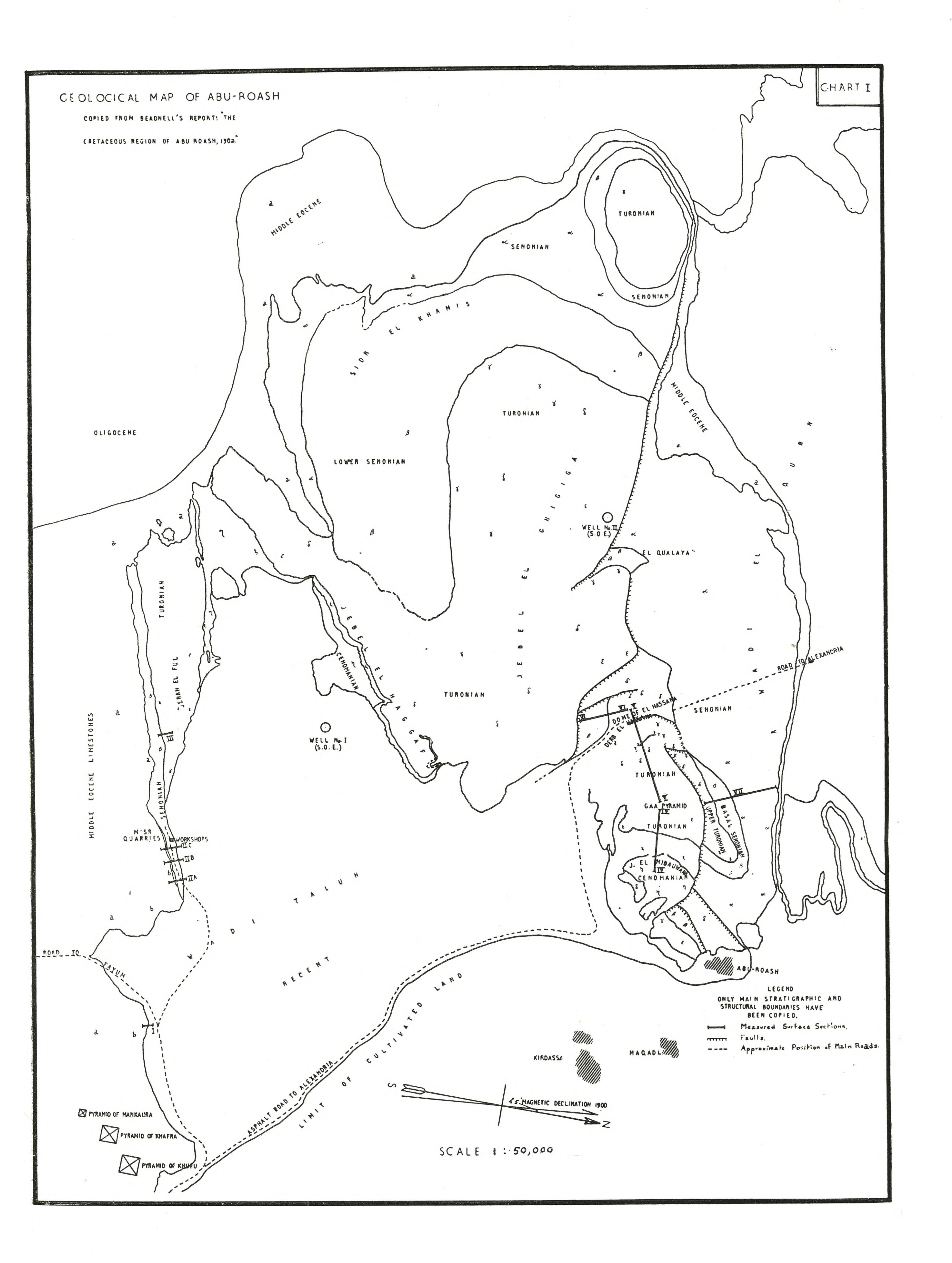
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GEOLOGICAL MAP OF ABU-ROASH
COPIED FROM BEADNELL'S REPORT: "THE CRETACEOUS REGION OF ABU ROASH, 1902"
CHART I
MIDDLE EOCENE
TURONIAN
SENONIAN
SENONIAN
SIDR EL KHAMIS
MIDDLE EOCENE
TURONIAN
OLIGOCENE
LOWER SENONIAN
EL QURN
WELL No. II (S.O.E.)
EL QUALAYA
JEBEL EL GHIGIGA
EL WADI
TURONIAN
JERAN EL FUL
JEBEL EL HAGGAF
CENOMANIAN
TURONIAN
ROAD TO ALEXANDRIA
WELL No. I (S.O.E.)
DOME OF EL HASSANA
DERB EL
SENONIAN
MIDDLE EOCENE LIMESTONES
SENONIAN
TURONIAN
GAA PYRAMID
TURONIAN
BASAL SENONIAN
UPPER TURONIAN
M'SR QUARRIES
WORKSHOPS
J. EL MIDAUWARA
CENOMANIAN
WADI TALUN
ROAD TO FAYUM
RECENT
ABU-ROASH
LEGEND
ONLY MAIN STRATIGRAPHIC AND STRUCTURAL BOUNDARIES HAVE BEEN COPIED.
Measured Surface Sections.
Faults.
Approximate Position of Main Roads.
KIRDASSA
MAQADI
LIMIT OF CULTIVATED LAND
ASPHALT ROAD TO ALEXANDRIA
PYRAMID OF MANKAURA
PYRAMID OF KHAFRA
PYRAMID OF KHUFU
4½° MAGNETIC DECLINATION 1900
S
N
SCALE 1 : 50,000

CHART II

LITHOLOGIC SURFACE SECTION OF

ABU-ROASH.

0 10 20 ms.

SAMPLE No.	THICKNESS in ms.	LITHOLOGY	COLOUR	OTHER DETAILS	NAMES OF LOCAL UNITS	AGE
3,2 20,19				Nummulites, Fasciolites		M.EOCENE
18, 6, 5, 4, 26, 17, 7, 24, 25, 8, 21, 22, 2, 15, 16, 9, 14, 10	100		whi / whi	Gryphea, Exogyra	UPPER CHALK SERIES	MAES. / CAMPANIAN — SENONIAN — UPPER CRETACEOUS
95 — 14 SAMPLES — 80	58		ye-whi	Partly chalky North Flank:- bedded, hard South Flank:- more argillaceous, partly chalky. Large Oysters & Plicatulas, many minute Serpula tubes, Hemiasters.	OSTREA–PLICATULA SERIES	SANTONIAN — SENONIAN — UPPER CRETACEOUS
79 — 9 SAMPLES — 71	45		whi	Flint near top, chert pieces up to 30cms. Coral: Phyllocoenia In places with flint, many globular masses of Millestroma, rich in Acteonella, Nerinea changing laterally into Biradiolites.	FLINT SERIES	TURONIAN — UPPER CRETACEOUS
67, 70, 64, 68, 65, 66, 69	10 / 30		(gr) / (r)	Small Oysters.	ACT.-HERN. SERIES	TURONIAN — UPPER CRETACEOUS
63 — 18 SAMPLES — 46	130		g / whi / whi	Massive L.S. In Central Part: Compact, bedded, practically unfossiliferous. On South Flank: Grey massive L.S.	CHALKY LIMESTONE SERIES	TURONIAN — UPPER CRETACEOUS
45 — 10 SAMPLES — 36	40		(br) M / whi L.S.	Oysters, Echinobrissus, Hemiaster. 40 cms. bed with Biradiolites, Sphaerulites.	RUDISTAE SERIES	CENOMANIAN — UPPER CRETACEOUS
35, 110, 109, 108, 107, 106, 105, 104, 34, 38, 30, 31, 32, 103, 96	30		g / L.S.	Multicoloured Ferruginous S.S., partly saliferous clays.	FERRUGINOUS CLAY SERIES	CENOMANIAN — UPPER CRETACEOUS

LEGEND.

MARL — MARLY L.S. — CHALKY MARLY L.S.
SANDY MARL — SHALE — SANDY GYPSIFEROUS SHALE
SANDY SHALE — LIMESTONE — CHALKY L.S. — L.S. LIMESTONE
CHALK — SANDY CHALK. — SAND — S.S. SANDSTONE.
ALTERNATION OF SHALE, S.S.& L.S. — ALTERNATION OF S.S.& L.S. — SANDSTONE — M MARL

g grey — cr cream — (cr) creamish — MACROFOSSILS
whi white — yl yellow — (br) brownish — PLANT REMAINS
br brown — gr green — l light — ● OIL SHOWS

CHART III

QUANTITATIVE GENERIC MICRO-FAUNAL CHART.

OF THE UPPER CRETACEOUS (SENONIAN–UPPER CENOMANIAN)

OF

ABU-ROASH

(SURFACE SECTION).

SAMPLE NUMBER	LOCALITY (SEE CHART I.)	STRATIGRAPHIC DISTANCE SEE CHART II	LOCAL NAMES OF UNITS	COLOUR
3	ON SOUTH SIDE OF ROAD TO FAYOUM IN FIRST LIMESTONE QUARRY JUST EAST OF JUNCTION WITH ROAD TO MISR QUARRY. (Section I)	Top	NUMMULITIC LIMESTONE	y
2		same as 3		
1		20m b.s 2		
20		1m above [illegible]		
19		same as 25		(c)
18	JUST BEFORE MISR QUARRY BUILDING ON SOUTH SIDE OF ROAD TO QUARRY, NEAR JERAN EL FUL. (Sections IIa, IIb & IIc)	All same level below unconformity	UPPER CHALK SERIES	wh.
6				
5				
4				
26				
17		2m b.s 26		
7				
24		1m. b.s 17		
25				
8				
21		2m. b.s 8		
22				
23				
16		2m b.s 23		
15		3m. b.s 16		(cr) wh.
9				wh.
14		1m b.s 9		(cr)
13		1m b.s 14		wh.
12		1m. b.s. 13		
11		1m b.s. 12		
10		1m. b.s. 11		
95	ABOUT 1½ KILOMETERS EAST OF EL HASSANA DOME, ON NORTH FLANK OF ABU ROASH BORDERING THE CHALK PLAIN. (Section VII)	1m. b.s 10	OSTREA-PLICATULA SERIES	
94		2m b.s 95		
93				
92		[illegible]m b.s 93		
91		10m b.s 92		
90		10m b.s 91		
89		10m b.s 90		
88		10m b.s. 89		
87		10m b.s 88		
85		2m b.s 87		
84		3m. b.s 85		
83		2m b.s. 84		
82		3m b.s 83		
80		7m. b.s 82		
79	SOUTH FLANK OF EL HASSANA DOME. (Section VI)	2m b.s 80	FLINT SERIES	
78		4m. b.s 79		
77		3m. b.s 78		
76		3m. b.s 77		
75		3m b.s 76		
74		5m b.s 75		
73		2m. b.s 74		
72		2m. b.s 73		
71		2m b.s 72		
70		15m b.s 71	ACTEONELLA-NERINEA SERIES	g
66	200 METERS SOUTH WEST OF GAA PYRAMID. (Section V)			(gr) g
67		7m b.s 70		wh.
65				
64		20m. b.s 65		
69				(br)
68		10m. b.s. 64		
63	AT BASE OF GAA PYRAMID AND THE UNDERLYING CLIFF EAST OF THE PYRAMID. (Section IV)		CHALKY LIMESTONE SERIES	wh.
62		2.5m. b.s 63		
61		2.5m. b.s 62		
60		4m. b.s 61		
59		3m. b.s. 60		
58		5m b.s 59		
57		3.5m b.s. 58		
56		4m b.s 57		
55		5m b.s. 56		
54		3.5m b.s 55		
53		3.5m b.s. [illegible]		
52		3.5m. b.s 53		
51		3.5m. b.s. 52		
50		4m b.s. 51		
49		2m b.s. 50		
48		5m. b.s. 49		
47				
46		6m. b.s. 47		
45	NORTH OF CAIRO ALEXANDRIA ROAD AT JEBEL EL MIDAUWARA AMPHITHEATRE (Section III)	just b.s 46	RUDISTAE SERIES	(cr)
44		3.5m b.s 45		(br)
43		1m b.s 44		(cr)
42		2m b.s 43		wh.
41		4m b.s 42		(cr)
40		3m b.s 41		yl
39		2m b.s 40		(br)
38		5m b.s 39		
37		5m b.s 38		wh.
35		0.5m b.s 37	FERRUGINOUS CLAY SERIES	(cr)
110				
34		1m. b.s. 110		yl
109		70cm. b.s 34		(yl) r
108		1.7m. b.s 109		(yl) g
107		1m b.s 108		g
33		1.6m b.s 107		
106		10cm. b.s 33		
30		90cm b.s 106		multi-coloured
105		80cm b.s 30		(yl)
104		1.7m. b.s 105		
31		0.5m. b.s 104		g
32				
103		20cm. b.s. 32		(yl) g
102		1m b.s 103		g
101		1.7m b.s 102		
100		90cm b.s 101		(yl)
99		80cm b.s 100		
98		2m b.s 99		
97		1m. b.s 98		(yl) g
96		2m b.s 97		(yl)

FORAMINIFERA

ARENACEA: AMMODISCIDAE (AMMODISCUS, TURRITELLELLA); LITUOLIDAE (AMMOBACULITES, AMMOMARGINULINA, CRIBROSTOMOIDES, FLABELLAMMINA, FRANKEINA, HAPLOPHRAGMOIDES, TRIPLASIA, TROCHAMMINOIDES); RHIZAMMINIDAE (BATHYSIPHON); TEXTULARIIDAE (BIGENERINA, TEXTULARIA); TROCHAMMINIDAE (TROCHAMMINA); VALVULINIDAE (ARENOBULIMINA, CLAVULINA, DOROTHIA, MARSSONELLA, MARTINOTTIELLA, TEXTULARIELLA, VALVULINA); VERNEUILINIDAE (PSEUDOGAUDRYINA, SIPHOGAUDRYINA, TRITAXIA, VERNEUILINA)

CALCAREA — IMPERFORATA: MILIOLIDAE (PYRGO, QUINQUELOCULINA, SIGMOILINA, TRILOCULINA)

CALCAREA — PERFORATA: ANOMALINIDAE (ANOMALINA, CIBICIDES); BULIMINIDAE (BOLIVINA, BULIMINA, BULIMINELLA, REUSSELLA, TURRILINA); CHILOSTOMELLIDAE (CHILOSTOMELLA, PULLENIA); CYMBALOPORIDAE (CYMBALOPORA); ELLIPSOIDINIDAE (ELLIPSONODOSARIA); GLOBIGERINIDAE (GLOBIGERINA, GLOBIGERINELLA); GLOBOROTALIIDAE (GLOBOROTALIA, GLOBOTRUNCANA); HETEROHELICIDAE (BOLIVINELLA, BOLIVINITA, BOLIVINOIDES, GUMBELINA, GUMBELITRIA, NODOGENERINA, PLANOGLOBULINA, PSEUDOTEXTULARIA, RECTOGUMBELINA, SIPHOGENERINOIDES, TUBITEXTULARIA, VENTILABRELLA); LAGENIDAE (DENTALINA, PALMULA, FRONDICULARIA, LAGENA, LENTICULINA, LINGULINA, MARGINULINA, NODOSARIA, PLANULARIA, PSEUDOGLANDULINA, ROBULUS, VAGINULINA); NONIONIDAE (NONION); POLYMORPHINIDAE (PALAEOPOLYMORPHINA, PYRULINA); ROTALIIDAE (DISCORBIS, EPISTOMINA, EPONIDES, GYROIDINA, ROTALIA, STENSIOINA)

NON-FORAMINIFERAL MICRO-ORGANISMS: BRACHIOPODA, COPROLITE, ECHINOID SPINE, FISH TEETH, GASTROPODA, OSTRACODA (ornamented), OSTRACODA (smooth)

MICRO-FAUNAL ZONES (top to bottom): *First sample with number of Globigerines exceeding Globigerinelles; VERNEUILINIDAE VALVULINIDAE ZONE; Quinqueloculina Zone; Rotalia-Trochammina-Lituolidae Zone; LITUOLIDAE ZONE; Trochammina Zone; TROCHAMMINIDAE; Rotalia Trochammina Zone; LITUOLIDAE ZONE

AGE: EOCENE — LUTETIAN; UPPER CRETACEOUS — SENONIAN (CAMPANIAN, SANTONIAN), TURONIAN, CENOMANIAN

L E G E N D

GRAPHIC SYMBOLS

Symbol		
....	VERY RARE	1 — 5
– –	RARE	6 — 10
—	COMMON	11 — 100
▬	ABUNDANT	101 — 1000
■	FLOODED	> 1000

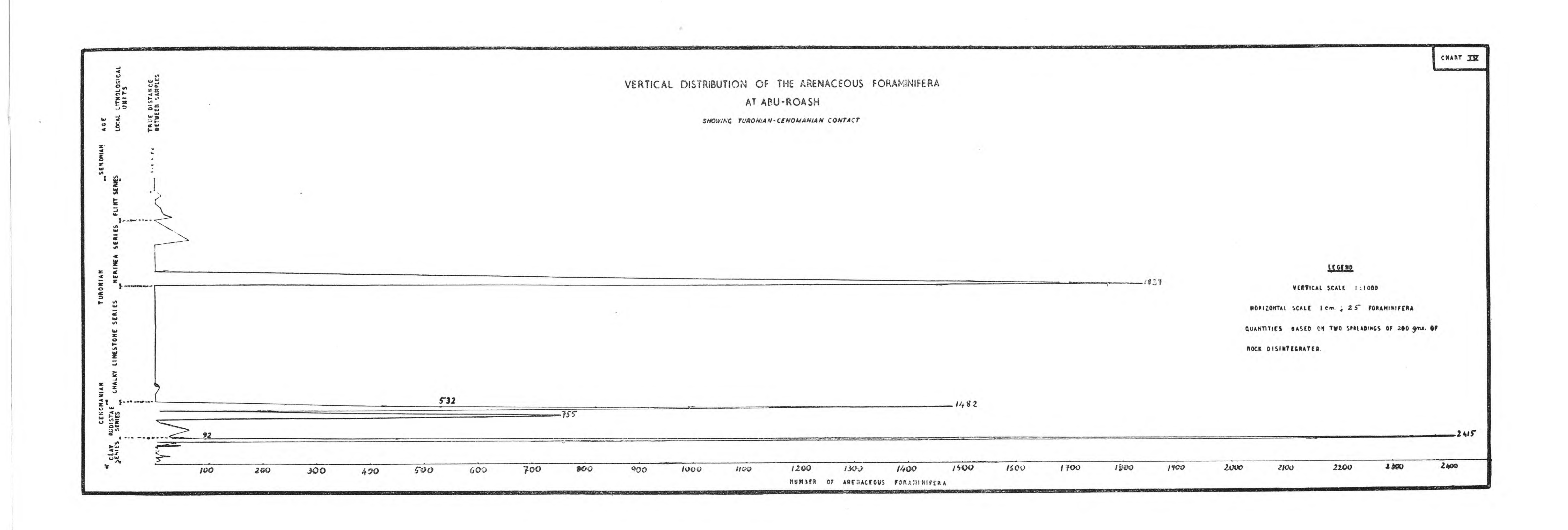
LITHOLOGY

MARL; MARLY LIMESTONE; CHALKY MARLY LIMESTONE; SANDY MARL; SHALE; SANDY GYPSIFEROUS SHALE; SANDY SHALE; LIMESTONE; CHALKY LIMESTONE; CHALK; SANDY CHALK; SAND; SANDSTONE; ALTERNATION OF SANDSTONE & LIMESTONE; ALTERNATION OF SHALE, SANDSTONE & LIMESTONE

COLOURS

g	grey	gr	green
wh	white	(cr)	creamish
br	brown	(br)	brownish
cr	cream	yl	yellow

b.s. below sample.


CHART IV
VERTICAL DISTRIBUTION OF THE ARENACEOUS FORAMINIFERA
AT ABU-ROASH
SHOWING TURONIAN-CENOMANIAN CONTACT
AGE
LOCAL LITHOLOGICAL UNITS
TRUE DISTANCE BETWEEN SAMPLES
SENONIAN
TURONIAN
CENOMANIAN
FLINT SERIES
NERINEA SERIES
CHALKY LIMESTONE SERIES
RUDISTAE SERIES
CLAY SERIES
532
1482
755
92
2415
LEGEND
VERTICAL SCALE 1:1000
HORIZONTAL SCALE 1 cm. ; 25 FORAMINIFERA
QUANTITIES BASED ON TWO SPREADINGS OF 200 gms. OF ROCK DISINTEGRATED.
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
NUMBER OF ARENACEOUS FORAMINIFERA

STUDIES ON THE PHYSIOLOGY OF HOST-PARASITE RELATIONS :

V. GROWTH AND PECTINASE ENZYME PRODUCTION BY THREE SOFT ROT BACTERIA ON MEDIA CONTAINING DIFFERENT SUGARS OR MIXTURES OF SUGARS WITH SPECIAL REFERENCE TO THE EFFECT OF SOME MICRONUTRIENT ELEMENTS.

BY

M. K. TOLBA, D. I. C., Ph. D. (London)

AND

S. S. GHANEM, M. Sc. (Cairo)

I. Introduction

Previous work on the physiology of parasitism showed that the ability of any particular fungus or bacterium to parasitise and cause a rotting of the host tissue is largely dependant upon its being able to secrete pectinase enzyme. Brown (2), Harter and Weimer (5), Hall (4), Jones (6), Robin (7), Gregg (3), Tolba (8-9) and several other investigators found that not only does the same organism show very different excretory powers according to the cultural conditions prevailing but also that the properties of its enzyme vary, somewhat, according to these conditions.

The aim of this investigation is to find out the effect of feeding three closely related soft rot bacteria, namely, *B. aroideae, B. carotovorum* and *B. phytophthorum* with different sugars or mixtures of sugars on their growth and power of pectinase enzyme production with special reference to the effect of some micronutrient elements on the above two phenomena.

II. Materials and Methods

The organisms used in this investigation were as follows :

1. *Bacterium aroideae,* Dowson, 66
2. *Bacterium carotovorum,* Jones.
3. *Bacterium phytophthorum,* Appel.

The three cultures were kindly supplied by the Plant Bacteriological Laboratory of the Imperial College of Science and Technology, London.

The technique used for the preparation of culture media, and determination of bacterial number and enzymic activity is that given in previous papers (8, 10 and 11).

III. Experimental Results

1. *Growth and Pectinase Enzyme Production by B. aroideae, B. carotovorum and B. phytophthorum Subcultured into Media Containing 2 % Sucrose, Glucose, Fructose or a Mixture of Glucose and Fructose.*

A. *Bacterial Growth :*

The number of viable bacterial cells per ml. culture medium are presented in Table 1. These results show that :

1. Growth of *B. aroideae* was best in the sucrose fed samples followed by glucose, then the mixture of glucose and fructose, while the least growth was obtained on fructose.

2. *B. carotovorum* thrived best on sucrose medium, with no appreciable differences between the bacterial numbers per ml., at the end of 48 hours, in media containing a mixture of glucose and fructose or when glucose and fructose were supplied separately. At the end of the first 24 hours no statistically significant differences were observed between the bacterial numbers in the different culture media.

3. The growth of *B. phytophthorum* was best on sucrose-containing media followed by glucose then the mixture of glucose and fructose and least in the fructose fed samples.

Table I

Bacterial Growth and Pectinase Enzyme Production by *B. aroideae, B. carotovorum* and *B. phytophthorum* on Culture Media Containing 2 % Sucrose, Glucose, Fructose or a Mixture of Glucose and Fructose.

Organism	Medium	Age of culture in hours			
		24	48		
		Bact. No./ml. X 10^6	Bact. No./ml. X 10^6	Enzymic Activity	
				Total	Per unit
B. aroideae	2 % Sucrose	292 ± 5.7	310 ± 6.2	240.0	0.77
	2 % Glucose	260 ± 4.9	272 ± 3.2	300.0	1.10
	2 % Fructose	192 ± 5.4	200 ± 2.6	240.0	1.20
	1 % Glucose + 1 % Fructose	216 ± 7.4	235 ± 7.1	333.3	1.42
B. carotovorum	2 % Sucrose	245 ± 3.3	262 ± 3.8	333.3	1.27
	2 % Glucose	235 ± 3.6	244 ± 4.9	300.0	1.23
	2 % Fructose	230 ± 4.2	245 ± 6.1	272.7	1.11
	1 % Glucose + 1 % Fructose	240 ± 4.4	247 ± 4.7	333.3	1.34
B. phytophthorum	2 % Sucrose	48 ± 2.4	60 ± 3.0	158.0	2.63
	2 % Glucose	25 ± 2.6	46 ± 2.7	120.0	2.63
	2 % Fructose	12 ± 1.2	20 ± 1.8	100.0	5.00
	1 % Glucose + 1 % Fructose	16 ± 1.1	27 ± 1.4	75.0	2.77

B. *Pectinase Enzymic Activity :*

The total pectinase enzymic and the enzymic activity per unit of the three bacteria in the different sugar media presented in Table 1. These results show that :

1. The enzymic activity per unit was highest, in case of *B. aroideae*, on the mixture of glucose and fructose, lowest on sucrose, while glucose and fructose, when supplied separately, led to the production of enzymes of intermediate activities between the two extremes. In case of *B. carotovorum* no substantial differences were observed the activities on the different culture media. *B. phytophthorum*, on the other hand, revealed its highest enzymic activity per unit in the fructose-containing media.

2. *B. phytophthorum* gave the highest values of enzymic activity per unit, in almost all cases, when compared with the other two organisms. This may be in compensation for the lower rate of growth exhibited by the former organism on all the media used.

3. On consideration of the total enzymic activities one can see that the mixture of glucose and fructose seems to be amongst the best suited sugar media for pectinase enzyme production by *B. aroideae* and *B. carotovorum*, while it appears to be least suited, in this respect, for *B. phytophthorum*.

2. *Growth and Pectinase Enzyme Production by B. aroideae, B. carotovorum, and B. phytophthorum Subcultured into Media Containing 2 % Lactose, Glucose, Galactose or a Mixture of Glucose and Galactose.*

A. *Bacterial Growth :*

The number of viable bacterial cells per ml. culture medium are presented in Table II. Table II shows that the best growth, of *B. aroideae* was attained on glucose, that *B. carotovorum* on the mixture of glucose and galactose, with no significant differences in the numbers of bacteria per ml. of the different media inoculated with *B. phytophthorum*.

TABLE II

Bacterial Growth and Pectinase Enzyme Production by *B. aroideae*, *B. carotovorum* and *B. phytophthorum* on Culture Media Containing 2 % Lactose, Glucose, Galactose or a Mixture of Glucose and Galactose.

Organism	Medium	Age of culture in hours			
		24	48		
				Enzymic Activity	
		Bact. No./ml. X 10^6	Bact. No /ml. X 10^6	Total	Per unit
B. aroideae	2 % Lactose	118 ± 7.0	143 ± 2.9	240.0	1.68
	2 % Glucose	225 ± 4.3	240 ± 4.3	300.0	1.25
	2 % Galactose	180 ± 3.7	196 ± 3.9	300.0	1.53
	1 % Glucose + 1 % Galactose	205 ± 3.7	219 ± 4.8	400.0	1.82
B. carotovorum	2 % Lactose	112 ± 3.8	160 ± 4.3	240.0	1.50
	2 % Glucose	198 ± 3.8	210 ± 5.4	333.3	1.60
	2 % Galactose	185 ± 3.0	205 ± 3.1	333.3	1.62
	1 % Glucose + 1 % Galactose	200 ± 3.4	223 ± 3.1	400.0	1.79
B. phytophthorum	2 % Lactose	13 ± 1.9	35 ± 2.0	133.3	3.81
	2 % Glucose	28 ± 1.5	42 ± 1.7	109.1	2.57
	2 % Galactose	22 ± 2.0	38 ± 3.1	171.4	4.51
	1 % Glucose + 1 % Galactose	26 ± 1.6	42 ± 3.2	171.4	4.08

B. *Pectinase Enzymic Activity :*

The results in Table II show that :

1. The enzymic activity per unit in case of *B. aroideae* was highest on lactose and the mixture of glucose and galactose and lowest on glucose. *B. carotovorum* revealed no substantial differences between the enzymic activities per unit on the different sugar media. *B. phytophthorum* gave

highest values of enzymic activity per unit on galactose and the mixture of glucose while lactose-fed samples gave intermediate values.

2. On comparing the enzymic activity per unit of the three bacteria in the different sugar media used it can be seen that *B. phytophthorum* gave the highest values when compared with the other two organisms.

3. Considering the total enzymic activity it can be seen that the mixture of glucose and galactose is best suited, whereas lactose seems to be least suited for total enzyme production by *B. aroideae* and *B. carotovorum*. *B. phytophthorum,* on the other hand, showed its highest enzymic activity on media containing galactose alone or a mixture of glucose and galactose, while its lowest enzymic activity was revealed on glucose-containing media.

Glucose and galactose, when supplied separately to the three bacteria, led to the production of an enzyme of almost the same activity.

3. *Growth and Pectinase Enzyme Production By B. aroideae, B. carotovorum and B. phytophthorum Subcultures into Culture Media Containing Different Concentration of Iron.*

A. *Bacterial Growth :*

The number of viable cells per ml. culture medium are presented in Table III. These results show that :

a. *B. aroideae :* The bacterial number per ml. at the end of 24 hours showed steady increase with increasing the concentration of iron in the medium up to 50 p.p.m. Presence of iron in a concentration of 100 p.p.m. slightly lowered the bacterial number than that of the control samples. At the end of 48 hours the bacterial number per ml. in culture media containing 10 and 20 p.p.m. iron was still higher than that of the control, while a sharp fall in the bacterial number was observed in media containing iron of higher concentrations, namely, 50 and 100 p.p.m.

TABLE III

Bacterial Growth and Pectinase Enzyme Production by B. aroideae, B. carotovorum and B. phytophthorum on Culture Media Containing Different Concentrations of Iron.

Organism	Concentration of iron in the medium	Age of culture in hours: 24 — Bact. No./ml. X 10^6	48 — Bact. No./ml. X 10^6	48 — Enzymic Activity: Total	48 — Enzymic Activity: Per unit
B. aroideae	0 p.p.m.	262 ± 3.6	270 ± 3.1	500.0	1.85
	10 p.p.m.	268 ± 4.3	282 ± 4.6	545.4	1.93
	20 p.p.m.	277 ± 3.1	293 ± 2.3	1000.0	3.41
	50 p.p.m.	290 ± 4.2	250 ± 2.8	850.0	3.40
	100 p.p.m.	255 ± 2.4	167 ± 1.3	545.4	3.26
B. carotovorum	0 p.p.m.	250 ± 2.1	260 ± 2.5	461.5	1.77
	10 p.p.m.	252 ± 5.7	275 ± 2.5	500.0	1.81
	20 p.p.m.	280 ± 3.1	288 ± 2.8	750.0	2.60
	50 p.p.m.	285 ± 2.6	248 ± 4.9	600.0	2.50
	100 p.p.m.	245 ± 5.4	205 ± 4.0	500.0	2.43
B. phytophthorum	0 p.p.m.	39 ± 1.2	56 ± 3.6	222.2	3.96
	10 p.p.m.	40 ± 1.2	60 ± 1.7	300.0	5.00
	20 p.p.m.	42 ± 1.4	65 ± 2.2	300.0	4.61
	50 p.p.m.	45 ± 1.2	46 ± 1.5	200.0	4.35
	100 p.p.m.	35 ± 1.7	35 ± 2.2	150.0	4.28

b. *B. carotovorum :* Presence of iron in concentrations of 20 and 50 p.p.m. led to a statistically significant increase in the bacterial number, at the end of the first 24 hours, over that of the controls and the media containing the other two concentrations of iron, namely, 10 and 100 p.p.m. The latter concentrations did not induce any material differences in the rate of growth of this organism when compared with the controls. At the end of 48 hours the bacterial number per ml. of culture media containing 10 and 20 p.p.m. iron was still higher than the controls.

Media containing 50 and 100 p.p.m. iron showed a sharp fall in their bacterial population at the end of that period.

c. *B. phytophthorum* : The only increase in the bacterial number per ml. over the controls, at the end of 24 hours, was observed in media containing 50 p.p.m. iron. At the end of 48 hours the number of bacterial cells per ml. was significantly higher than that at the end of 24 hours in the control samples and in the media containing 10 and 20 p.p.m. iron. Culture media containing 50 and 100 p.p.m. iron, on the other hand, revealed the same number of bacterial cells per ml. culture medium as that observed at the end of the first 24 hours.

B. *Pectinase Enzymic Activity* :

The total pectinase enzymic activity as well as the enzymic activity per unit of the three bacteria in the different media are presented in Table III. These results show that :

1. In case of *B. aroideae* and *B. carotovorum* the enzymic activity per unit was higher when iron was present in the medium in concentrations above 10 p.p.m. than the controls. In case of *B. phytophthorum* the presence of iron, in its various concentrations, in the culture media increased the enzymic activity per unit than that of the controls. The highest activity, however, was observed on media containing 10 p.p.m. iron with a steady decrease on increasing the iron concentration.

2. The same high values of enzymic activity per unit revealed by *B. phytophthorum* in the previous experiments, when compared with the other two organisms, was again observed here.

3. On consideration of the total enzymic activity of the three bacteria one can see that in case of *B. aroideae* and *B. carotovorum* the presence of iron at a concentration of 20 p.p.m. led to the production of an enzyme of the highest activity with a fall in the activity at either sides of this concentration. *B. phytophthorum,* on the other hand, showed its highest enzymic activity when iron was present at the concentrations of 10 and 20 p.p.m. Increasing the concentration of iron above 20 p.p.m. markedly reduced the enzymic activity of the latter organism.

4. *Growth and Pectinase Enzyme Production by B. aroideae, B. carotovorum and B. phytophthorum Subcultured into Culture Media Containing Different Concentration of Copper.*

The results of this experiment showed that the presence of copper in the medium markedly reduced the growth of the three bacteria as compared to the control samples. Increasing the concentration of copper was accompanied by a drastic fall in the bacterial number per ml. culture medium in case of the three bacteria, most pronounced when copper was present at concentrations above 20 p.p.m.

The results also showed that the enzymic activity per unit increased with increasing the concentration of copper in the medium in case of the three bacterial organisms. This fact may be explained on the basis of either that *a*) the toxicity of copper is exercised on the bacterial multiplication but not on its power to secrete the enzyme. The small bacterial population produced in presence of copper secretes bigger amounts of enzyme per cell to compensate for the reduction in number. Or, that *b*) copper exerts its toxic effect on the bacteria after they are produced, thus the enzyme so obtained in the medium is in fact secreted by a bigger number of bacterial cells than that obtained in the counts for viable cells.

Generally speaking *B. phytophthorum* gave higher values of enzymic activity per unit as compared to the other two organisms in all culture media.

The presence of copper in the medium did not materially affect the total enzymic activity of the three bacteria when compared with the control sets except, probably, a slight reduction in the activity of pectinase enzyme secreted by *B. phytophthorum*.

5. *Growth and Pectinase Enzyme Production by B. aroideae, B. carotovorum and B. phytophthorum Subcultured into Culture Media Containing Different Concentrations of Zinc.*

The results of the present experiment showed that :

1. The presence of zinc in the culture medium did not affect the growth of the three bacteria as compared to the control samples except, probably, a slight reduction in the bacterial number in case of

B. aroideae and *B. phytophthorum* when zinc was present at a concentration of 100 p.p.m. in the culture medium.

2. The enzymic activity per unit was not materially affected by the presence of zinc in its different concentrations in case of *B. aroideae* and *B. carotovorum*. *B. phytophthorum* responded to the presence of zinc, in its different concentrations, by producing enzyme of much higher activity than the control samples though varying the concentration of zinc did not materially affect the enzymic activity of that organism.

3. *B. phytophthorum* gave much higher values of enzymic activity per unit as compared to the other two organisms in all culture media.

4. The presence of zinc in concentrations between 10 and 50 p.p.m. did not materially affect the total activity of *B. aroideae* whereas when present in its highest concentration, *viz.*, 100 p.p.m., it induced a reduction in the total enzymic activity than of the controls. The presence of zinc in all concentrations markedly reduced the total activity of the enzyme secreted by *B. carotovorum*. In case of *B. phytophthorum* the total enzymic activity was higher in media containing zinc in concentrations between 10 and 50 p.p.m. than the control sets.

IV. Summary of Conclusion

1. The growth and power of pectinase enzyme production by *B. aroideae, B. carotovorum* and *B. phytophthorum* was studied on different culture media containing various sugars or mixtures of sugars with special reference to the effect of some micronutrient elements.

2. *B. aroideae* and *B. carotovorum* multiplied very rapidly in their culture media during the first 24 hours with a much slower rate of multiplication during the second 24 hours. Such difference in the rate of multiplication was not so much exaggerated in case of *B. phytophthorum*.

3. *B. aroideae* thrived best on sucrose, least on lactose, with the other sugars or mixtures of sugars occupying intermediate positions. In case of *B. carotovorum* lactose was the only sugar which revealed significantly

lower values of bacterial numbers than the other sugars or mixtures of sugars. *B. phytophthorum* showed highest values on sucrose media, lowest on fructose and the mixture of glucose and fructose while the other sugars or mixtures of sugars gave, more or less, similar, values which lie in between the above two extremes.

4. Presence of iron in the culture medium at a concentration of 20 p.p.m. appeared to be optimal for the growth of *B. aroideae* and *B. carotovorum*. The optimal concentration for the growth of *B. phytophthorum* seems to lie between 10 and 20 p.p.m. Presence of zinc in the culture medium did not materially affect the growth, while the presence of copper markedly reduced the growth of the three bacteria as compared to the control samples.

5. Feeding the three bacteria with different sugars or mixtures of sugars led to the production of varied amounts of pectinase anzyme. Presence of micronutrient elements affected the power of pectinase enzyme production by the three bacteria in different ways.

B. phytophthorum showed much higher values of pectinase enzymic activity per unit than the other two organisms on almost all culture media used.

6. The results of this investigation support the view that the culture medium suitable for the growth of a certain bacterial organism may not be quite suitable for the production of pectinase enzyme by the same organism.

V. Literature cited.

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STUDIES ON THE PHYSIOLOGY
OF HOST-PARASITE RELATIONS

VI. PHYSIOLOGICAL ANALYSIS OF THE SUSCEPTIBILITY OF THREE TOMATO VARIETIES GROWING IN EGYPT TO ATTACK BY *FUSARIUM CULMORUM* AND *FUSARIUM OXYSPORUM*.

BY

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I. INTRODUCTION

The problem of the resistance of plants to fungal or bacterial attack is of great practical importance. If the nature of resistance of a particular plant to a particular pathogen is understood, the plant breeder may be able to combine the factors for resistance to disease with other desirable factors and so produce a resistant variety of higher quality.

Resistance may be due to the structure of the host plant (Brooks (2) and Ghamrawy (9). The presence in the plant of some substances which inhibit the growth of a particular fungus frequently confers a measure of resistance. The immunity of monocotyledonous plants to the cotton root-rot fungus, *Phymatotrichum omnivorum,* has been attributed by Ezekiel and Fudge (8), to be in part due to the presence of acids in the cell sap.

Specific substances in the plant may favour some fungi and inhibit others (Hooker, Walker and Link (16)).

Some substances such as phenols and tannis were reported by Cook and Wilton (6), Lutz (17), Newton and Anderson (20), Greathouse and Rigler (13), Dufrenoy and Edgerton (7) and Cartwright and Findlay (5) to be generally associated with resistance.

Haussmann (14) found that the resistance of different apple varieties to attack by several fungi, including some *Fusarium* species, was due to the physiological properties such as sugar-content, acidity of juice, under-ripeness, etc., of each variety.

The object of this work is to study certain aspects of the chemical composition of three tomato varieties showing different degrees of susceptibility to attack by two *Fusarium* species as well as the cultural behaviour of these two Fusaria with a view to discovering what features are primarily responsible for such differences.

II. MATERIALS AND METHODS

Three tomato varieties were used in this investigation, namely, Pritchards, North Dakota and IAB. The three varieties were kindly supplied by the Ministry of Agriculture, Vegetable Research Station, Giza.

Two *Fusarium species* [1] were used viz., *Fusarium culmorum* (Smith) Saccardo and *Fusarium oxysporum* Schlecht.

Stock cultures were maintained, at laboratory temperature, on Dox's agar slopes. For experimental purposes, cultures seven days old were used throughout. 0.2 ml. of fungal spore suspension in sterile water or a standard disc cut out from agar cultures in Petri-dishes was added, under aseptic conditions, to each of a series of 150 ml. flasks containing 10 ml. per flask of the sterilised culture medium or to each fruit of the different tomato varieties under test. Control samples, inoculated with sterile water or sterile agar discs free from mycelium were kept. In all experiments the flasks or fruits were incubated at 25°C.

The method used for inoculation of tomato fruits was more or less that given by Granger and Horne (12).

The pH-values of the different cultural fluids were determined by the B.D.H. capillators or indicator papers with a range of difference of 0.2 units.

The power of the fungus to produce pectinase enzyme was tested by examining both the crude external culture media for the exo-

[1] The author is greatly indebted to Dr. W. L. Gordon of the Dominion Rust Research Laboratory, Winnipeg, Manitoba, Canada for identifying the *Fusarium* species.

enzyme and the crude endo-enzyme according to the methods described by Brown (3 and 4).

Other methods which have been used from time to time in connection with various experiments will be described in the appropriate sections of the text.

III. EXPERIMENTAL RESULTS

a. *Relative Susceptibility of the three Tomato Varieties to Attack by the Two Fusaria.*

In this series of experiments green and red fruits of the three tomato varieties were used. Fruits were collected from crops growing under the same field conditions. They were chosen to be, nearly of the same age and size. Twenty replicates were used for each treatment. Each

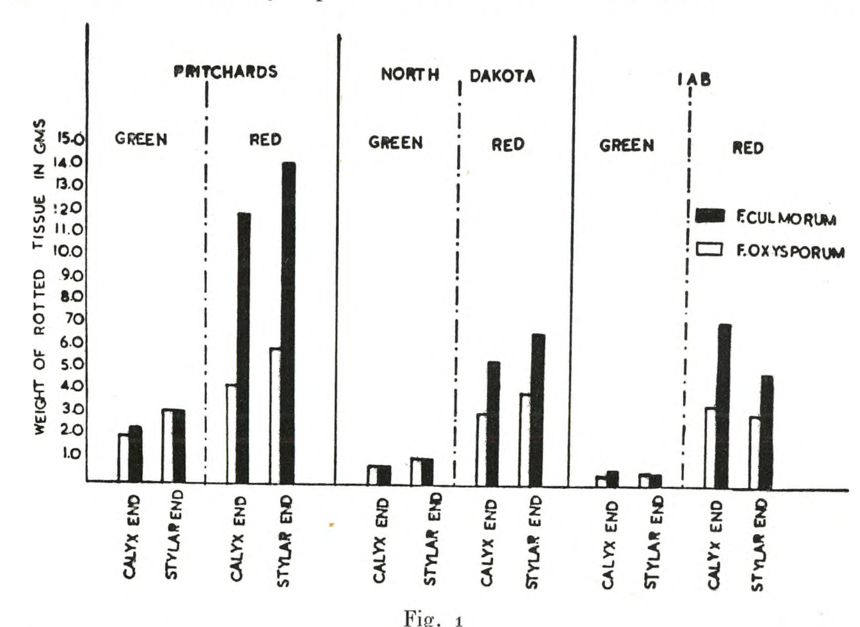


Fig. 1

Amount of rotted tissue produced by *F. culmorum* and *F. oxysporum* inoculated into the tissue of fruits of Pritchards, North Dakota and IAB tomato varieties.

fruit was inoculated at the calyx and stylar ends. The fruits were incubated at 25°C for four days. The rotted tissue after the experimental period was then scraped off and weighed. The average values of the results obtained from this set of experiments are presented in fig. 1.

Statistical analysis of the results in fig. 1 showed that :

1. The differences in susceptibility of the tomato varieties to attack by the two *Fusarium* species are statistically significant. Pritchards variety proved to be the most susceptible while the other two varieties did not show any substantial differences in their susceptibilities.

2. Red fruits of the three varieties showed higher susceptibility to attack by the two fungi than the corresponding green ones.

3. The stylar ends of the green and red fruits of Pritchards and North Dakota varieties gave higher values of rotted tissue than the corresponding calyx ends. No such differences were observed in case of green fruits of IAB variety. The calyx ends of the red fruits of the latter variety showed higher susceptibility to attack than the stylar ends.

b. *Analysis of Tissues of Different Tomato Varieties for their Carbohydrate, Nitrogen and Water-contents as well as their pH-values.*

The results of the previous experiments revealed marked variations in the susceptibility of the different portions of green and red fruits of the three tomato varieties to attack by the *Fusarium* species. With a view to discovering the possible reasons for such varied susceptibilities, tomato fruit tissue was analysed with respect to its content of carbohydrate, nitrogen and water as well as its pH-value, to find out if there were any differences in the chemical composition of the various tissues that might reflect some light upon the nature of the factors governing these variations in susceptibility to attack.

The results of these analyses are presented in another paper (Tolba and Saleh (23) and they can be summarised as follows :

1. The variations in pH-value and water-content of the different parts of green and red fruits of the three tomato varieties are too small but a definite correlation between the pH-value of tissue and the amount of rot produced by the two Fusaria used in this investigation was found (Tolba and Saleh (24)). The susceptibility of tomato tissue to attack seems to decrease with the increase in its pH-value.

2. Green fruits of the three varieties showed limited variations in their amino-N and reducing sugar-contents. Red fruits, on the other hand, varied considerably with regards these two aspects. The red fruits of Pritchards variety showed the highest content of amino-N and reducing sugars when compared with the other two varieties. Those of North Dakota and IAB did not differ markedly with regards their contents of reducing sugars but the former variety contained more amino-N than the latter.

3. The stylar ends of green and red fruits of the three varieties, in almost all cases, showed higher values of amino-, total soluble- and total-nitrogen fractions as well as reducing sugars than the calyx ends. The only exception to the above conclusion was the case of red fruits of IAB variety which showed greater amounts of reducing sugars in the calyx than the stylar ends.

c. *Growth of the Two Fusaria on Fruit Decoctions of the Different Tomato Varieties.*

Before trying to interprete the varied susceptibility revealed by the rot measurement experiments in the light of the results of the chemical analyses, a trial was made to grow the two fungi on decoctions of the different tomato varieties.

Tomato juice and extract were prepared and sterilised by autoclaving at 15 lb. pressure for 15 minutes or according to the technique devised by Menon (19).

The juices and extracts were then distributed into a series of sterile 150 ml. conical flasks and inoculated with each of the two fungi.

After five days incubation at 25°C., the dry weights of the mycelia produced on the different culture media were determined. The pH-values of the culture fluids at the beginning and end of the experiment were also determined.

The results of these experiments showed that :

1. Cold-sterilised juice of the green fruits of the three varieties

furnished, in almost all cases, smaller mycelial growth of the two fungi than that of the corresponding red ones.

2. Cold-sterilised juice of green and red fruits of Pritchards variety supported better growth of the two *Fusarium* species than the other two varieties.

3. The extract of fruits of all varieties and stages of maturity supported very scanty growth of the two fungi.

4. Autoclaved juice of green and red fruits of Pritchards variety proved to be less suited for the growth of the two fungi than the cold-sterilised one, a fact which may be attributed to the possible destruction of some carbohydrate and nitrogen components during the process of autoclaving. The autoclaved juice of the green fruits of IAB and North Dakota varieties, on the other hand, supported better growth of the two fungi than the corresponding cold-sterilised juices. The results obtained with red fruits of these two varieties were rather inconsistent and showed no statistically significant differences.

These facts indicate that the juice of green fruits of IAB and North Dakota varieties, probably, contains thermolabile substances which inhibit the growth of the two fungi.

5. The juice collected from the stylar ends of the three varieties supported better growth of the two fungi than that of the corresponding calyx ends, except in the case of red fruits of IAB variety where the results were rather inconsistent.

d. *Fungal Growth on Synthetic Culture Media.*

As mentioned earlier the behaviour of the two Fusaria on tomato juice was strickingly different and this established the necessity of studying the effect of the two constituents of tomato juice examined in this investigation, namely carbohydrate and nitrogen fractions. For this purpose the use of a synthetic medium approximately equivalent to tomato would prove of great advantage. In proceeding to compound such a medium, a start was made from a typical tomato analysis. Such

analysis (Tolba and Saleh, (23)), showed that the major carbohydrate components are the reducing sugars and to a much lesser extent the poly-saccharides. The important nitrogen constituent is the amino-N, followed by the amide- and proteinic-N fractions.

A synthetic medium of the following composition was thus prepared :

Glucose	1500	mgm.
Starch	300	»
Peptone-N	75	»
Asparagin-N	25	»
Glycine-N	125	»
KH_2PO_4	100	»
$Mg SO_4 . 7H_2O$	50	»
KCL	50	»
$FeSO_4 . 7H_2O$	1	»
Distilled water to	100	ml.

The amounts of glucose and starch added are considered to represent the average values of reducing sugars and polysaccharides respectively met with in the different tomato tissues analysed. Peptone, asparagin and glycine are assumed to be equivalent to the average values of the complex nitrogen, amide-N and amino-N fractions respectively of the nitrogen-containing constituent of the tomato fruit. Glycine was reported by Anderson and Emmort (1) and Glottleib (10) to be among the best suited amino acids for the growth of *F. oxysporum*.

A series of media were also prepared in which each of the carbohydrate and nitrogen constituents in turn was omitted. The original pH-values of the different media were adjusted to that of the control, viz., pH 5.5.

The culture media so prepared were inoculated with the fungi in the usual way. After five days incubation at 25°C, the mycelial dry weights and final pH-values of the different culture media were determined.

The results showed that asparagin and starch did not seem to induce any effect on the growth of the fungi while omission of glycine, peptone and glucose resulted in a marked reduction of the values of the mycelial dry weights of the two fungi.

On the basis of the above results the following carbohydrate and nitrogen components of the synthetic medium were considered as substantially affecting the fungal growth : glucose, peptone and glycine. A medium of the following composition was thus compounded to give a fair substitute for the essential carbohydrate and nitrogen fractions present in tomato tissue :

Glucose	1500	mgm.
Peptone-N	75	»
Glycine-N	125	»
KH_2PO_4	100	»
$MgSO_4 \cdot 7H_2O$	50	»
KCL	50	»
$FeSO_4 \cdot 7H_2O$	1	»
Distilled water to	100	ml.

This medium when tested for its suitability for the growth of the two *Fusarium* species gave values for mycelial dry weights more or less similar to those obtained on the complicated medium used before.

This simple medium was thus made the basis for studying the effect of the composition of the nutrient medium, from the point of view of its carbohydrate-and nitrogen-contents, on the behaviour of the two fungi under test. Starting from the above formula it was varied both as regards concentration, the ratio between the carbon and nitrogen components being kept constant and as regards composition, the ratio of these components being varied in different directions.

It must be borne in mind that in these experiments the effect of varying C : N ratio was complicated, although to a small extent, by variations in the nature and concentrations of the nitrogen components which would naturally entail variations in the amounts of carbon attached to them.

The results of this experiment are presented in Tables I and II and they show that :

1. Increasing the concentration of nitrogen while keeping the values of glucose constant led to some increase in the mycelial dry weight in case of *F. culmorum*. *F. oxysporum*, on the other hand, did not seem to

be affected to any appreciable degree by variations in the concentrations of nitrogen in the culture medium especially when glucose was present in its highest concentration.

TABLE I.

Effect of Varying the C : N Ratio of the Culture Medium on the Growth of *F. oxysporum*

Concentration of Nitrogen (mgm.)	Concentration of Glucose (mgm.)			
	1000	1500	2000	2500
125	39 ± 0.4	53 ± 0.0	67 ± 0.4	89 ± 0.4
150	42 ± 0.4	55 ± 0.0	70 ± 0.0	88 ± 0.4
175	43 ± 0.0	57 ± 0.6	73 ± 0.0	87 ± 0.4
200	43 ± 0.4	57 ± 0.0	71 ± 0.4	87 ± 0.0
225	44 ± 0.4	59 ± 0.0	74 ± 0.4	89 ± 0.4
250	47 ± 0.0	56 ± 0.4	74 ± 0.0	88 ± 0.4

TABLE II.

Effect of Varying the C : N Ratio of the Culture Medium on the Growth of *F. culmorum*

Concentration of Nitrogen (mgm.)	Concentration of Glucose (mgm.)			
	1000	1500	2000	2500
125	37 ± 0.0	53 ± 0.4	60 ± 0.4	73 ± 0.6
150	39 ± 0.3	56 ± 0.6	66 ± 0.4	75 ± 0.8
175	44 ± 0.0	60 ± 0.6	65 ± 0.0	78 ± 0.0
200	44 ± 0.4	60 ± 0.4	68 ± 0.6	80 ± 0.4
225	51 ± 0.4	60 ± 0.0	72 ± 0.4	87 ± 0.4
250	55 ± 0.0	60 ± 0.4	75 ± 0.0	88 ± 0.8

It may be argued, however, that the increase in concentration of nitrogen is accompanied by variations in the relative amounts of glycine and peptone added to the medium, a fact which would lead to

erroneous interpretation of the results but when pairs of media with the same ratios of peptone to glycine but with varying concentrations of both were compared the same conclusions mentioned above were reached.

2. Increasing the concentration of glucose while keeping the values of nitrogen constant led to a marked increase in the growth of the two *Fusarium* species. This effect was more pronounced in case of *F. oxysporum*.

3. Diluting both glucose and nitrogen constituents simultaneously while keeping the ratio between them constant led to a marked reduction in the values of the mycelial dry weights of the two *Fusarium* species, a fact which again indicates the importance of the high concentration of carbohydrate and nitrogen components of the tomato tissue in governing their susceptibility to attack by fruit-rot inducing Fusaria.

The results of the above series of experiments showed that the two fungi were affected to different extents by varying the ratios of carbon to nitrogen. As stated earlier, these ratios were complicated through variations in the amounts of carbon attached to the nitrogen sources used. In order to test for the effect of varying the C : N ratio of the medium without taking into consideration the actual nature of the nitrogen constituents present in tomato tissue, a simple medium was used in which the nitrogen source was in the form of sodium nitrate.

The results of this experiment showed that :

1. Synthetic media with sodium nitrate as nitrogen source were much less suited for the growth of *F. culmorum* than those with peptone and glycine. The growth of *F. culmorum* on the former media was too scanty and did not seem to respond, to any appreciable extent, to variations in the concentrations of nitrogen and carbon sources.

2. The growth of *F. oxysporum*, expressed in terms of mycelial dry weight, was very much increased with increasing the concentration of glucose while keeping the nitrogen concentration constant. Varying the concentration of nitrogen source while keeping that of glucose constant did not seem to affect the growth of *F. oxysporum*.

3. Diluting the nitrogen and carbon constituents simultaneously

while keeping the ratio between them constant resulted in a marked reduction in the amount of growth of the two fungi, most pronounced in case of *F. oxysporum*.

Analysis of the tissue of the different tomato varieties examined showed that the values of glucose in the different samples were ranging between 1.11 and 1.36 those of fructose. The latter sugar was reported by several investigators to affect fungal growth in a different way from glucose (Tamiya (22); Steinberg (21); Herric (15); Margolin (18); Wolf and Shoup (25) and others).

A trial was thus made to find out the effect of fructose when incorporated with glucose in the synthetic culture medium on the growth of the two *Fusarium* species, and it was found that the use of glucose alone or a mixture of glucose and fructose as sources of carbon in the culture media did not induce any appreciable effect on the growth of the two fungi when the nitrogen source was in the form of sodium nitrate or peptone and glycine.

e. *Pectinase Enzymic Production by F. culmorum and F. oxysporum on Natural and Synthetic Culture Media.*

As mentioned earlier several investigators reported that the ability of any particular fungus or bacterium to parasitise and cause a rotting of the host tissue is largely dependent upon its being able to secrete an active pectinase enzyme which attacks the cell wall middle lamella and thereby causes a loss of coherence of the host cells.

A trial was thus made to find out if the two species of Fusarium used in this investigation secrete such an enzyme and to see whether the activity of that enzyme varies on the different culture media or not.

The exo—and endo—enzymes of the two fungi were prepared on a variety of media, namely, squeezed rotted tissue of the different tomato varieties, cold-sterilised juice of tomato, tomato extract and synthetic culture media.

The enzymic activities were tested by Brown's (3) disc method.

The results of these series of experiments showed that the two fungi failed, almost completely, to secrete pectinase enzyme of any considerable activity on all culture media tested including the tomato tissue

itself. This result may be interpreted on the basis of the assumption that the attack by the two Fusaria on tomato tissue is either purely mechanical or is affected by some chemical substances other than pectinase enzyme.

In a way of confirming the above results the rotted tissue of the different tomato fruits was microscopically examined at various intervals from the time of inoculation with the two fungi. No separation of the host cells, as is expected through the action of pectinase enzyme, was traced in these investigations.

IV. DISCUSSION

As mentioned before the aim of this investigation was to find out if there was any correlation between certain aspects of the chemical composition of the three tomato varieties under test and their varied susceptibility to attack by two fruit rot-inducing fungi, namely *F. culmorum* and *F. oxysporum*.

The results recorded in the present investigation revealed the following facts :

a. Firstly that Pritchards variety was more susceptible to attack by the two *Fusarium* species used than both North Dakota and IAB. Chemical analysis of the tissue of the three tomato varieties showed that red fruits of Pritchards variety contained more reducing sugars and amino-N than those of the other two varieties. The latters did not differ markedly from one another with regards their contents of reducing sugars, but fruits of the North Dakota variety revealed higher amino-N-contents than those of IAB variety. Green fruits of Pritchards and IAB varieties did not show any substantial differences in their contents of reducing sugars, but they both showed higher values of these sugars than the corresponding fruits of the North Dakota variety. The green fruits of the three varieties did not reveal substantial differences in their amino-N-contents.

Growth of the two *Fusarium* species on tomato decoctions showed that their growth was governed, to a large extent, by the nature of the decoction. This eliminated or, at least, reduced the possibility that the mechanical structure of the three varieties plays any important role in determining their susceptibility to attack by those fungi.

Fungal growth on synthetic culture media showed that the glucose, glycine and peptone were the carbohydrate and nitrogen components respectively most effective on the amount of growth of the two fungi. It was also found that increasing the glucose concentration of the culture medium while keeping the value of nitrogen constant led to a marked increase in the amounts of total growth of the two fungi. A similar result, though to a much lesser extent, was obtained through increasing the amount of nitrogen while keeping the value of glucose constant.

The pH-value of the different tomato tissues examined, varied between pH 4 and pH 5. Such variation in the pH-value, though quite limited, seems to be correlated with the susceptibility of the different tomato varieties to attack by the two *Fusarium* species used in this investigation. The authors (24) found that the susceptibility of tomato tissue to attack by these two Fusaria decreases with the increase in its pH-value. It thus appears that the pH-value of the tomato tissue is among the factors governing its susceptibility to attack by those two Fusaria.

The higher susceptibility of red fruits of the Pritchards variety to attack by the two fungi than the other two varieties may be correlated with the high reducing sugars- and nitrogen-contents of the former than the latters on the one hand and the slightly lower pH of tissue of the former variety than the latters on the other. This statement may just as well partly explain the higher susceptibility of green fruits of Pritchards variety than those of the North Dakota variety but would not satisfactorily explain the lower susceptibility of green fruits of IAB variety which contains almost as much reducing sugars as those of the Pritchards variety. The most probable explanation for this varied susceptibility would be the slightly lower pH of tissue of the latter than the former.

A comparison of the growth of the two fungi on autoclaved and cold-sterilised juices of the three varieties revealed the possibility of the

presence of a thermolabile inhibitory susbstance in the green fruits of IAB and North Dakota varieties, most pronounced in case of IAB. Such substance was not found in Pritchards variety. The presence of such inhibitory substance may be in part responsible for the lower susceptibility of North Dakota and IAB green fruits when compared with those of the Pritchards variety.

b. The red fruits of the three varieties proved to be more susceptible to attack by the two fungi than the green ones. This may be generally correlated with the higher pH-value of the latter than the formers. The higher susceptibility of red fruits of Pritchards variety may be also correlated with their higher contents of reducing sugars and nitrogen than the green ones. The latter statement, however, fails to explain the difference in susceptibility of green and red fruits of North Dakota and IAB varieties which showed no substantial differences in the reducing sugars-and nitrogen- contents of the corresponding green and red fruits. Again examination of the values of mycelial dry weights on cold-sterilised and autoclaved juices of these two varieties showed that the green fruits probably contain a thermolabile inhibiting substance which is almost absent in the red ones. It seems, therefore, that the lower susceptibility of the green fruits of these two varieties than the corresponding red ones may be due to the higher pH-value of tissues of green fruits than the corresponding red ones as well as to the presence of thermolabile inhibiting substances in the formers and not the latters.

c. The stylar ends of both green and red fruits of the three varieties proved to be more susceptible, in almost all cases, to attack than the corresponding calyx ends. Results of the analysis of tomato tissue led to the suggestion that such higher susceptibility of the stylar ends may be due to the higher contents of nitrogen and reducing sugars than the calyx ends. The only exception to the above conclusion was the case of the red fruits of IAB variety which showed higher susceptibility of their calyx ends to attack by the two fungi than the stylar ends. This fact may be also correlated with the higher content of reducing sugars revealed by the calyx than the stylar ends of these fruits.

V. SUMMARY

1. The susceptibility of three tomato varieties growing in Egypt, namely, Pritchards, North Dakota and IAB to attack by two fruit rot-inducing fungi, viz. *F. culmorum* and *F. oxysporum* was studied.

2. Pritchards variety was more susceptible to attack than the other two varieties.

3. Red fruits of the three varieties were more susceptible than the green ones.

4. The stylar ends of tomato fruits, in the majority of cases, were more susceptible to attack than the corresponding calyx ends.

5. The mechanical structure of tomato fruits did not seem to play any important role in governing their relative susceptibilities to fungal attack.

6. Variations in the pH-values of tissues of different tomato varieties were too small but proved to be correlated with the susceptibility of tomato tissue by the two Fusaria. The susceptibility of tomato tissue decreases with the increase of its pH-value.

7. The variations in the susceptibility of green and red fruits of the three tomato varieties seem to be correlated with :

a. pH of tomato tissue.

b. Reducing sugars- and amino-N-contents of the tissue.

c. Presence or absence of thermolabile inhibiting susbstances in the tissue.

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LES CÉPHALOPODES CRÉTACÉS
DU MASSIF DU MOGHARA,
(SINAÏ-ÉGYPTE)

(NOTE COMPLÉMENTAIRE À L'OUVRAGE DE H. DOUVILLÉ)

PAR

IBRAHIM GAMAL EL-DIN MAHMOUD, Dr. ès-Sc.

Ces fossiles ont été étudiés par H. Douvillé (1916)[1] qui n'a pu séparer de façon sûre les espèces de l'Aptien inférieur (Bédoulien) de celles du Barrémien supérieur et qui cite les espèces suivantes :

Barrémien : *Lytoceras Liebigi* Opp., *Lytoceras sutile* Opp., *Costidiscus recticostatus* d'Orb., *Phylloceras semistriatum* d'Orb., *Ph. infundibulum* d'Orb., *Desmoceras hemiptychum* Kilian, *Crioceras* (*Acanthodiscus*) *hammatoptychum* Uhl., *Cr.* cf. *obliquatum* d'Orb., *Cr.* cf. *dilatatum* d'Orb.

Aptien : *Pseudobelus aptiensis* Stoll., *Duvalia* cf. *Grasi* Duv.-J., *Puzosia Matheroni* d'Orb., *P. Angladei* Sayn, *Crioceras* cf. *simplex* d'Orb., *Douvilleiceras Meyendorffi* (d'Orb.) Sinz., *Nautilus Lallieri* d'Orb., *Knemiceras priscum* H. Douv.

La révision de ces déterminations m'a donné la liste suivante :

Neohibolites aptiensis Stoll. (pl. 17, fig. 1). Aptien.

N. sp. indet. (sine fig.) (p. 90, 12e ligne). Barrémien?

[1] H. Douvillé, *Les Terrains Secondaires dans le Massif du Moghara à l'Est de l'Isthme de Suez,* d'après les *Explorations de M. Couyat-Barthoux*. Paléontologie par H. Douvillé, 1re et 2e parties, t. LIV, 2e série, Paris 1916, 184 pages, XXI planches.

Duvalia cf. *Grasiana* Duv.-J. sp. (sine fig.). Aptien?
Heminautilus Lallierianus d'Orb. sp. (pl. 17, fig. 2 à 6). Aptien.
Hypophylloceras aff. *robionense* Collign. sp. (pl. 12, fig. 1 et 2). Barrémien.
Phyllopachyceras aff. *Argonauta* Schloth. sp. (pl. 12, fig. 3). Barrémien.
Hemilytoceras aff. *subsequens* Karak. sp. (pl. 2, fig. 1, 2). Barrémien.
H. nov. sp. (?) (pl. 2, fig. 3, 4 et 5). Barrémien.
Barremites hemiptychus W. Kill. (pl. 12, fig. 7). Barrémien.
Pseudohaploceras Douvillei P. Fall. sp. (pl. 13, fig. 1 à 7, lectotype fig. 2). Barrémien.
Valdedorsella cf. *Angladei* Sayn sp. (pl. 13, fig. 8 et 9). Aptien.
Procheloniceras pachypleura (H. Douv.) (pl. 15, fig. 6). Aptien.
Mogharaeceras priscum H. Douv. sp. (pl. 16, fig. 7 et 8). Aptien?
Costidiscus recticostatus d'Orb. sp. var. aff. *crassa* W. Kil. (pl. 2, fig. 7). Barrémien.
Paracrioceras hammatoptychum Uhl. sp. (pl. 14, fig. 1 à 5). Barrémien.
Hemibaculites aff. *obliquatus* d'Orb. sp. (pl. 15, fig. 3 et 4). Barrémien.
Heteroceras (?) nov. sp. (pl. 15, fig. 2). Barrémien.
Dirrynoceras aff. *simplex* d'Orb. sp. (pl. 15, fig. 5). Aptien?

Les Céphalopodes albiens les plus caractéristiques étudiés à l'époque par H. Douvillé sont :

Latidorsella latidorsata Mich., *Desmoceras Beudanti* Brong., *Douvilleiceras mamillare* Schloth., *Tetragonites* cf. *Duvali* d'Orb., *Hamites* cf. *compressus* Sow., *Crioceras* cf. *munieri* Sarasin et Schöndelmayer, *Knemiceras Uhligi* Choffat.

Autres espèces : *Lytoceras vicinum* H. Douv., *Knemiceras gracile* H. Douv., *Silesites nepos* H. Douv.

J'ajoute ici une liste, également révisée, de ces dernières espèces qui semblent représenter à la fois le sommet de l'Aptien supérieur (Clansayesien) et l'Albien inférieur ou tout au plus infra-moyen :

Ammonoceratites visinus H. Douv. sp. (pl. 2, fig. 6). Clansayesien.
Eotetragonites aff. *umbilicostriatus* Collign. (pl. 2, fig. 8 et 9). Albien.

Desmoceras (=*Latidorsella*) cf. *latidorsata* [1] Michel sp. (pl. 12, fig. 4 à 6). Albien.
Beudanticeras aff. *Walleranti* Jacob sp. (pl. 12, fig. 8). Albien.
Neposiella nepos H. Douv. sp. (pl. 15, fig. 8 = type, fig. 9 var. nov.). Albien.
Douvilleiceras cf. *mammillatum* Schloth. sp. (stade « clavatus ») (pl. 15, fig. 7). Albien.
Knemiceras Douvillei Basse 1940, em. Breistr. 1942 (pl. 16, fig. 4). Albien.
Knemiceras compressum Hyatt (pl. 16, fig. 3, fig. 2 var.). Albien.
Kn. aegyptiacum nov. nom. (pl. 16, fig. 5 = type et fig. 6). Albien.
Kn. gracile H. Douv. (pl. 16, fig. 9). Albien.
Hamites aff. *compressum* Sow. (Sine fig.) p. 96. Albien.
Protanisoceras trituberculatum Collign. sp. (var. ?) (pl. 15, fig. 1). Albien.

Les Céphalopodes caractéristiques de l'Albien inférieur et moyen, du Moghara, que j'ai signalés [2], sont :

Salfeldiella (*Aphroditiceras*) *Aphrodite* Fall. et Term. var. *Venus* nov. var.
S. (*Goretophylloceras*) *Moreti* nov. sp.,
Hypophylloceras (?) nov. sp. inédite.,
H. (*Hyporbulites*) *aegyptiacum* nov. sp.,
Eotetragonites Breistrofferi nov. sp.,
Protanisoceras aff. *trituberculatum* Collign.,
Desmoceras (= *Latidorsella*) *latidorsata* Mich. in d'Orb.,
Valdedorsella Gignouxi nov. sp.,
Puzosia aff. *communis* Spath, *Puzosia lata* Seitz, *P.* sp. indet.,

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[1] Espèce très polymorphe à nombreuses variétés. Fig. 4 est une forme assez fortement costulée, appartenant à un type primitif qui semble directement dériver de *Valdedorsella skuschaensis* Anth. sp. (Gargasien). Fig. 6 est assez typique. Fig. 5 représente un jeune à test lisse.

[2] Thèse 1952, Lab. Géol. Grenoble (p. 67 à 165, pl. I à V, texte-fig. 18 à 48).

Beudanticeras Revoili Perv. sp. var. *elegans* nov. var.,
Neposiella nepos H. Douv., *N. Spathi* nov. sp., *N.* sp. indet.,
Knemiceras Spathi nov. sp., *Kn. Spathi* var. *orientalis* nov. var.,
Knemiceras aegyptiacum nov. nom., *Kn. Collignoni* nov. sp.,
Kn. Rittmanni nov. sp., *Kn. deserti* nov. sp.,
Kn. aff. *gracile* H. Douv., *Kn. compressum* Hyatt, *Kn.* sp. indet.

Révision des espèces, les moins connues, de KNEMICERAS *du Moghara.*

H. DOUVILLÉ, comme nous l'avons déjà dit, avait signalé trois espèces de ce genre :

1. « *Knemiceras* » *priscum* (?) H. Douv. (pl. 16, fig. 7 et 8) dont plusieurs échantillons ont été trouvés dans les calcaires à fines oolithes ferrugineuses du Bir Lagama et du gebel Manzour (Aptien).

2. *Kn. gracile* H. Douv. (pl. 16, fig. 9). Il s'agit d'une espèce, rare, dont un seul échantillon a été trouvé dans les calcaires jaune à oolithes ferrugineuses assez grosses, au Nord-Ouest du Talat el Fallahin, associée à *Douvilleiceras mammillatum.*

3. *Kn.* « *Uhligi* » H. Douv. (non Choff.) (pl. 16, fig. 1 à 6). C'est l'« espèce » qui est représentée par un grand nombre d'échantillons provenant des couches albiennes de la coupe classique au Sud du Gebel Manzour et sur son versant Est. Cette « espèce » se trouve également au Nord du Gebel Oum Rekeba, dans des calcaires jaunes, tendres, présentant des oolithes ferrugineuses assez grosses et peu nombreuses. D'après H. DOUVILLE, elle existe encore sur le versant Ouest du Gebel Oum-Rekeba et du Talat el-Fallahin.

La première espèce, nageuse, est de forme discoïde, très aplatie, mince dans la région externe, avec deux carènes très rapprochées, séparées par une gouttière et plus renflée dans le voisinage de l'ombilic qui est très étroit. Les flancs, dépourvus d'ornementation, présentent seulement des lignes d'accroissement falciformes, caractère totalement différent de ceux des *Knemiceras* (au moins chez les adultes). De plus, elle ne possède pas une cloison typique de *Knemiceras* (1916, p. 122, texte-fig. 37 et 38).

BREISTROFFER (1940) a signalé que cette espèce rappelle beaucoup, par sa double carène externe, *Pulchellia Dutrugei* d'Algérie, ou son synonyme (?) d'Espagne *P. Sauvageoni*. C'est en effet un Pulchelliidé type du genre *Mogharaeceras* Breistr., se distinguant par ses cloisons knémiceratiformes des *Subpulchellia.*

La deuxième espèce est de forme mince et dépourvue d'ornementation (forme essentiellement nageuse). Ses carènes sont légèrement denticulées. En raison de sa forme très aplatie, de l'absence de toute sorte d'ornementation, de sa cloison dont les éléments sont relativement simples (*ibid.*, p. 128, texte-fig. 42) et de sa région externe étroite, H. DOUVILLÉ a rapproché cet échantillon du genre *Engonoceras,* mais les différences qui existent, surtout dans la cloison, montrent, que ce rapprochement ne peut être maintenu.

En effet, cette espèce peut être considérée comme très voisine de l'espèce *Kn. deserti* nov. sp. du Gebel Manzour.

La troisième « espèce » constitue un groupe de formes différentes des précédentes, un peu épaisses et très ornées, représentant des types néritiques. De fait, on trouve dans les couches riches en échantillons de ce groupe, les grands Mollusques : *Natica, Tylostoma, Protocardium, Trigonia,* etc. Ces formes sont plus ou moins renflées, à tubercules latero-externes n'alternant pas des deux côtés du pourtour externe plus ou moins élargi, mais au contraire presque opposés et reliés entre eux d'un côté à l'autre par des bourrelets déprimés. Elles sont donc bien distinctes de l'espèce portugaise, créée par CHOFFAT en 1886.

Il est à remarquer que sous le nom erroné de *Kn.* « *Uhligi* », H. DOUVILLÉ, 1916, pl. 16, avait figuré six échantillons (que j'ai consulté dans les collections de l'Ecole des Mines à Paris).

Fig. 1, est un petit échantillon de 16 mm. de diamètre, « stade clavatus ». Il est préférable, en l'occurrence, de ne pas insister sur la position systématique exacte de cet individu.

Fig. 3, est assez typique, appartenant à l'espèce *Kn. compressum* Hyatt. Il ne s'agit pour la fig. 2, que d'une variété inédite de cette dernière espèce.

Fig. 4, à cloison inconnue, est l'Holotype de l'espèce *Kn. Douvillei* Basse 1940 em. Breistr. 1942 = *Kn.* « *Uhligi* » ap. H. Douvillé.

Fig. 5, est l'Holotype de *Kn. aegyptiacum* nov. nom. = *Kn.* « *Uhligi* » ap. H. Douvillé.

Fig. 6, appartient à la dernière espèce et présentant le stade présénile.

Je dois signaler ici que M. Knechtel 1947, dans sa publication « Mesozoic Fossils of the Peruvian Andes », a décrit un échantillon moyen de 46 mm. de diamètre sous le nom de *Kn.* « *Sommermeieri* » et qui ne diffère guère de l'espèce *Kn. attenuatum* var. *semicostata* Sommermeier (considéré comme l'espèce représentative sud-américaine du *Kn. Spathi* méditerranéen et de sa variété) que par une allure plus simple des selles de la cloison. Cette particularité ne semble qu'une variation tout à fait individuelle qu'on ne peut absolument pas considérer comme un caractère spécifique chez le genre *Knemiceras* (comme je l'ai constaté au cours de mes études des espèces du Moghara).

De même, il a créé, sans justification aucune, pour un seul individu de 99 mm., l'espèce *Kn.* « *Moorei* ». Pour séparer cette « nouvelle » espèce de *Kn. attenuatum-semicostata* Somm., Knechtel se base uniquement sur l'attenuation de l'ornementation, à savoir la disparition des tubercules ombilicaux et l'affaiblissement des côtes sur les flancs de cet individu adulte. Or, j'ai déjà signalé dans ma thèse qu'on assiste, au cours du développement des espèces du genre *Knemiceras* du Moghara, à une simplification progressive de l'ornementation, dont l'atténuation dans les plus grands échantillons est régulière et donc uniquement en rapport avec l'âge de l'individu (phénomène de gérontisme).

En résumé, l'étude des caractères les plus essentiels, tirés soit de la forme et du mode d'ornementation, soit de la constitution des cloisons, montre qu'il ne s'agit en réalité que de deux individus de l'espèce *Kn. attenuatum-semicostata* Somm., à deux stades différents du développement.

ANATOMICAL IDENTIFICATION OF PLANT REMAINS AND OTHER MATERIALS[1]

FROM

(1) EL-OMARI EXCAVATIONS AT HELWAN FROM NEOLITHIC PERIOD;

(2) THE EXCAVATIONS AT HELWAN FROM THE FIRST DYNASTY

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Part I

EL-OMARI EXCAVATIONS AT HELWAN FROM NEOLITHIC PERIOD

Neolithic

The site of El-Omari (plate I, figs 1-4) is 3 km. to the North-East of Helwan-les-bains. It lies on the uppermost terrace of the River Nile at the edge of the Helwan plateau (Middle Eocene Limestone) near the mouth of Wadi Hof, a dried stream bed. The site was first referred to by Bovier-Lapierre (1925) and was later excavated by Mr. F. Debono, revealing two cemetries and a village.

El-Omari site is a predynastic settlement. According to Debono (1948), this predynastic culture belongs to the Culture-group of Lower Egypt represented by Merimde and Maadi. It is chronologically placed in between these two civilisations : earlier than Maadi.

Together with the various stone-implements and pottery, were excavated, bones and horns of different animals, ostrich egg shells, sheet of

[1] Communication présentée en séance du 19 avril 1954.

cloth, mats, ropes, food-stores, baskets, charcoal and various plant remains.

The following is a list of plant materials identified by the writer with their reference numbers in Debono's collection of El-Omari deposited in the Cairo Museum.

1. A 16 — *a piece of a rope.*
Leaves of Desmostachya bipinnata; Numerous Uredospores and rare Teleutospores of a *Puccinia sp.* were found parasiting these leaves.

2. A 16 *Room C — Hairs :* Sheep wool.
The hairs were identified according to descriptions given by Glaister (1931).
It is here interesting to refer to what Lucas (1948) recorded : Herodotus (II, 81) mentions the wearing of loose white woollen mantles over linen tunics and Deodorus (1,6) states that the Egyptian sheep yielded wool for clothing and ornament. According to Reisner (1907-1908), Firth (1908-1909) and Brunton 1927, woollen garments have been found in graves of the early christian period.
A piece of a rope—*Desmostachya bipinnata.* Plate II (figs. 1-4). Morphological differences between Desmostachya bipinnata and Imperata cylindrica were previously recorded by Simpson (1932).

3. A 20 — Reed fragments, 5-8 cm. long :
Phragmites communis var. isiacus. Plate III (figs., 1 *a*, 3, 4).

4. A 28 — room a — Remains of a rope :
Desmostachya bipinnata. (Leaves).

5. A 29 — room 9 — fibrous material, remains of a rope :
Desmostachya bipinnata. (Leaves).

6. A 34 — (I) as above;
(II) chestnut hair — human hair.

7. A 34 — (IV) fibrous material :
Cyperus sp.

8. A 34 (V) fibres — remains of a rope :
Leaves and culm of *Desmostachya bipinnata.*

9 A 34 — (VI) fibrous material :
(*a*) Leaves of *Desmostachya bipinnata.*
(*b*) Leaves of *Triticum sp.*

10 A 34 — (VII), (VIII), (IX) and (X) :
Leaves of *Desmostachya bipinnata.*

11 A 35 — A piece of rope embedded in a waxy material :
Desmostachya bipinnata leaves.

12 A 76 — (I), (II), (IV) and (V) :
Remains of rope of various thickness : *Desmostachya bipinnata leaves.*

13 A 76 — (III) human hair.

14 A 76 — (VI) twigs of *Tamarix sp.* According to Schweinfurth (1886); Herodote (II, 96) reported the presence of Tamarix trees very early in Egypt.

15 A 91 — (I) A piece of sheep skin with wool of different colours.

16 A 91 — (II) and (III) Remains of ropes :
Leaves of *Desmostachya bipinnata.*

17 A 101 — (9) A piece of a mat :
Leaves of *Phragmites communis.*

18 A 112 — Fragments of a reed :
culm of *Phragmites communis var. mauritianus.* Plate III (fig. 1 *b*, 2).

19 A 115 — (I) An 8 cm. long piece of a reed :
culm of *Phragmites communis var. mauritianus.*

20 A 155 — (II) a piece of a rope :
Leaves of *Desmostachya bipinnata.*

21 A 128 — fruits of *Ficus sycomorus.*
Schweinfurth (1886) mentioned the presence of three holly trees, *i. e.* Mimusops, Sycomore and Olive in ancient Egypt; and those were used in funeral decorations.

22 A 136 — A piece of a mat used as coffin :
culms of *Cyperus sp.* and *Phragmites communis var. mauritianus.*

23 A 151 — (I) a piece of a rope :
Leaves of *Desmostachya bipinnata.*

24 A 151 — (II) A piece of a culm :
Phragmites communis var. (*mauritianus.*

25 A 163 — (a) part of a mat :
culms of *Cyperus sp.*

25 B 9 (I), charred grains and straw of *wheat.*

27 A 76 — (I) a rope : 20 cm. long :
Leaves of *Desmostachya bipinnata.*

28 (II) piece of culm of *Phragmites communis var. mauritianus.*

Part II

THE EXCAVATIONS AT HELWAN FROM THE FIRST DYNASTY

First Dynasty

The site of this excavation lies on one of the Nile terraces in the Helwan district, 2 km. to the west of Helwan-les-bains. The excavation work started in 1942 under the direction of Prof. Zaki Saad. The site is an archaic cemetery that dates back, according to Prof. Saad, to the First Dynasty. The name of King Semer-Khet, the Sixth King of the First Dynasty, is engraved on two of the pottery jars discovered in the site. Other archaeological, architectural and cultural evidences authenticate the dating of the site. Among the objects excavated also from the second and third dynasty, were numerous containers, jars and pots made of alabaster, yellow limestone and diorite. Cosmetic impliments, scent-containers, bracelets and jewellery were also found.

Some of these objects together with ivory and faience utensils have engravings of flowers or leaves of recognisable plants such as *Phoenix dactylifera* and *Chrysanthemum coronarium.*

Fruits, seeds and several plant remains were collected, basket-coffins containing mumies of children and relics of other coffin materials were also collected. Ropes, brooms, mats and many objects of fibres were excavated.

The following is a list of materials identified by the writer with their reference numbers in the Museum of Helwan Excavation.

1. *Tomb* n° 48/H6 :

Remains of a coffin made of interwoven plants. Plants (stem and root only) of *Ceruana pratensis* Plate IV-(figs. 1 and 2).

Delile (1813) reported that in prehistoric times, entire plants were used in Upper Egypt for basket making, vessel covers, brooms etc. Keimer (1932) identified ancient basket-coffins, brooms etc. as made up of *Ceruana pratensis* from the study of the floral parts of the plant.

2. *Tomb* n° 53/H 7.

A basket-coffin, enclosing the mummy of a child, complete with cover. The object is made of 3 different plants :

(*a*) The skeleton is made of culms of *Cyperus Papyrus;* Plate V. (figs. 1-4).

(*b*) The filling between culms is made of strips of leaves *of Desmostachya bipinnata :* and

(*c*) The filling and the skeleton are lashed with stem-splits of *Ceruana pratensis.*

3. *Tomb* n° 54/H 6.

A basket-coffin of a child. The skeleton of the basket is made of culms of *Cyperus papyrus,* the filling and lash-strips are split culms of *Cyperus papyrus.*

Boats, cordage, sandals, mats, boxes, basket-coffins and other miscellaneous objects made up of papyrus culms were found by several workers among the ancient Egyptian remains starting from the predynastic period.

Kunth (1826), Schweinfurth (1886), Petrie and Quibell (1896), Petrie (1898), Bonnet (1905), Plowman (1906), Newberry (1912), Breasted (1917), Carter (1923-1933), Baikie (1925), Keimer (1927), Emery and Saad (1938), Lucas (1948) and Greiss (1949) referred to the finding of papyrus culms and sometimes to their uses.

4. *Tomb* n° 36/H 5.

Fibrous material associated with a coffin remains. Light and dark golden colour ; *human hair.*

5 *Tomb* n° 683/H 4 (1st-2nd Dynasty).

Bundles of thin sticks. The sticks are about 20 cm. in length and

18.

2-3 mm. in diameter. They are dark brown in colour with whitish striations. Stems of *Juncus arabicus* Plate IV (fig. 3).

Pens, mats, baskets, sieves and sandals made up of Juncus culms were found by several investigators among the ancient Egyptian remains from times immemorial. Garstang (1907), Theophrastus (1916) Petrie (1927), Bruyère (1927), Crowfoot (1933), Lucas (1942 and 1948) and Greiss (1949) gave a good deal of information about Juncus.

6. *Tomb* n° 72/H 4 (1st-2nd Dynasty).
Part of a rope. Twisted split-culms of *Cyperus papyrus*.

7. *Tomb* n° 261/H 5.
A piece of cloth, probably remains of a coffin. It is worthy to mention in this connection, as Lucas (1948) reported, that according to Caton-Thompson (1926), Brunton and Caton-Thompson (1928) and Brunton (1927) linen fabrics have been found from the neolithic, Badarian and predynastic periods respectively.

8. *Tomb* n° 141/H 4.
A piece of whitish cloth.

9. *Tomb* n° 491/H 4.
Remains of brown cloth.

10. *Tomb* n° 493/H 4.
Remains of brown cloth.

11. *Tomb* n° 539/H 4.
A piece of thin cloth, brown in colour.

12. *Tomb* n° 538/H 4.
Remains of a mummy wrappings.
White in colour — cloth of different thickness.

13. *Tomb* n° 580/H 4.
A piece of whitish cloth.

14. *Tomb* n° 640/H 4.
A piece of dirty white cloth.

15. *Tomb* n° 683/H 4 (B).
A large mummy wrapping of different thickness.

16. *Tomb* n° 683/H 4 (B).
Small bags of white cloth.

17. *Tomb* n° 672/H 4.
A long rope, thick, brown in colour. Brunton and Caton-Thompson (1928) reported that ropes were known very early in Egypt and the earliest specimens recorded was one from the predynastic period and was made of flax fibre.

Materials with serial numbers from 8 to 17 are made of fibres, of *Linum usitatissimum*.

18. *R. H* 8.
A 7 cm. long stick, with bifurcate branches each 3 cm. long. Each of the two branches carries a receptacle about 8 cm. in length covered with silvery hairs arranged in tiers.

The material is a pedicel carrying remains of fruits of *Calotropis, sp.* See photographs of this old material compared with a modern specimen. Plate VI (fig. 1-3).

19. *Tomb* n° 491/H 4.
Hairs stuck to a piece of cloth :
human hair, auburn in colour.

20. *Tomb* n° 494/H 4.
A stiff plant; a stem and root without leaves and inflorescences. *Ceruana pratensis.*

21. *Tomb* n° 499/H 4.
The material is : Human hair.

22. *Tomb* n° 500/H 4 : Golden hair

23. *Tomb* n° 635/H 4 : Golden hair

24. *Tomb* n° 646/H 4 : Blond hair.

25. *Tomb* n° 821/H 4 : Dark golden hair.

26. *Tomb* n° 31/H 4 : Dark hair

27. *Tomb* n° 55/H 11 : Golden hair.

28. *Tomb* n° 143/H 11 : Golden hair.

29. *Tomb* n° 902/H 1 : Golden hair.

Materials with serial numbers from 21 to 29 are *Human hair.*

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Fig. 1.—A view of a part of El-Omari site.

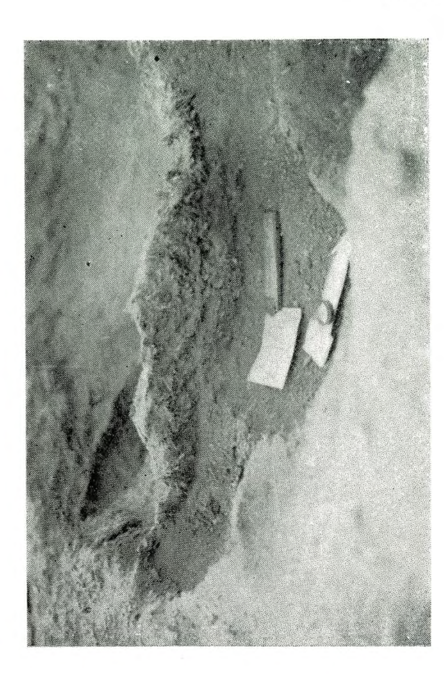
Fig. 2.—A food store before the excavation.

Fig. 3.—A food store after the excavation, where the plant remains were found.

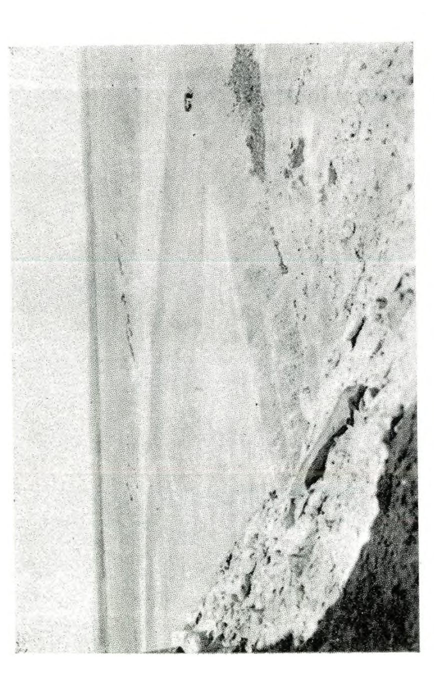
Fig. 4.—A basket containing grains in a food store (Photos by curtesy of M. F. Debono).



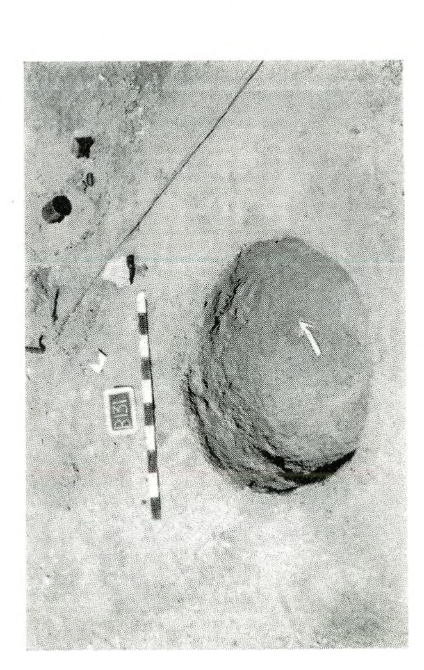
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Halfa grasses

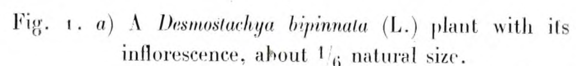


Fig. 1. *a*) A *Desmostachya bipinnata* (L.) plant with its inflorescence, about 1/6 natural size.

b) A plant of *Imperata cylindrica* (Beauv.) with ist inflorescence, about 1/6 natural size. Note the great resemblance between of the leaves the two plants.

Fig. 2.—Part of a mat (number A 34 I Debono's El-Omari excavation) made of *Desmotachya bipinnata* leaves.

Fig. 3.—Cross section through the middle region of *Imperata cylindrica* leaf × 18.

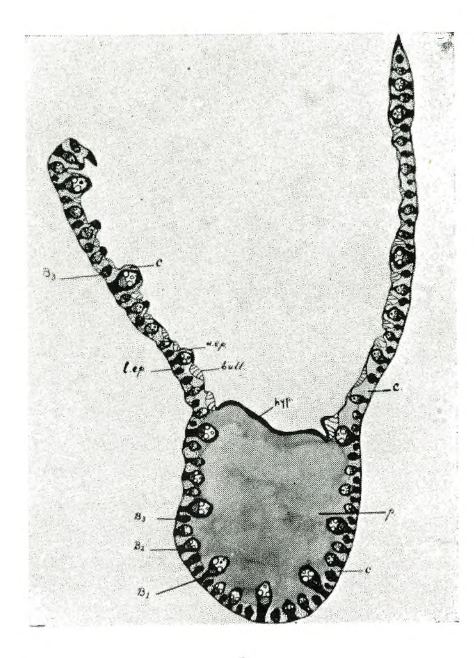
Fig. 4.—Cross section through the middle region of *Desmostaclya bipinnata* leaf × 18. Note the difference in structure between the two sections.

Abbreviations used

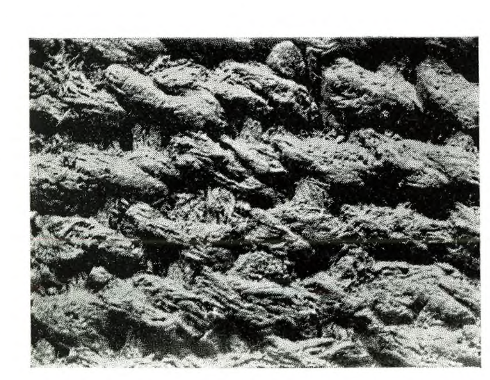
aig., aiguillon.
ass. band., assimilatory band.
B 1., bundle of the first order.
B 2., bundle of the second order.
B 3., bundle of the third order.
bull., bulliform cell.
c., chlorenchyma.
comp. bull., complement of the bulliform cells.
en. sh., endodermal sheath.
F., stereome.
g., groove.
l. ep. lower epidermis.
l. fl. lower fibrous flange.
p., parenchyma.
ph. f., phloem fibres.
sil., silica-containing cell.
st., stoma.
u. ep. upper epidermis.
u. fl., upper flange.



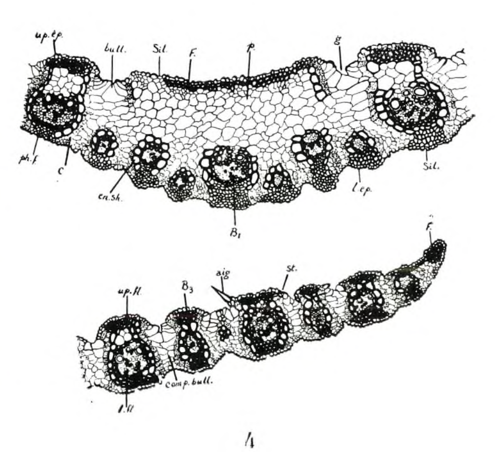
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4

Fig. 1. *a*) *Phragmites communis* (L.) *var. isiacus* (Del.) culm. The leaves are remooved from the lower part of the culm; about $^1/_{40}$ natural size.

b) *Phragmites communis* (L.) *var. mauritianus* (Kunth) culm. The leaves are remooved from the lower part of the culm; about $^1/_{40}$ natural size. Note the resemblance between the naked parts of the two culms.

Fig. 2.—Epidermal tissue of a *modern* culm of *Phragmites communis var. mauritianus* (much enlarged).

Fig. 3.—Epidermal tissue of a *modern* culm of *Phragmites communis var. isiacus* (much enlarged).

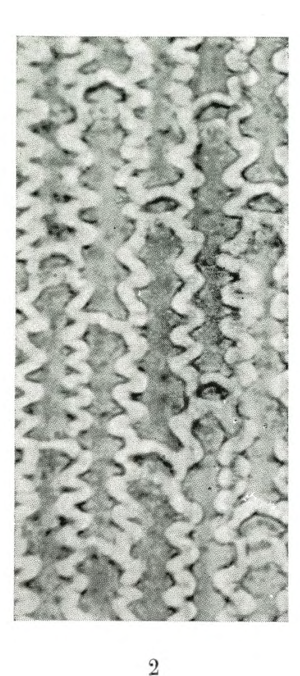
Fig. 4.—Epidermal tissue of an *ancient* culm of *Phragmites communis var. isiacus* (much enlarged).

The epidermal tissue is seen in surface view. Note the striking difference in the rippling of the walls of the epidermal cells, between fig. 2 and fig. 3.

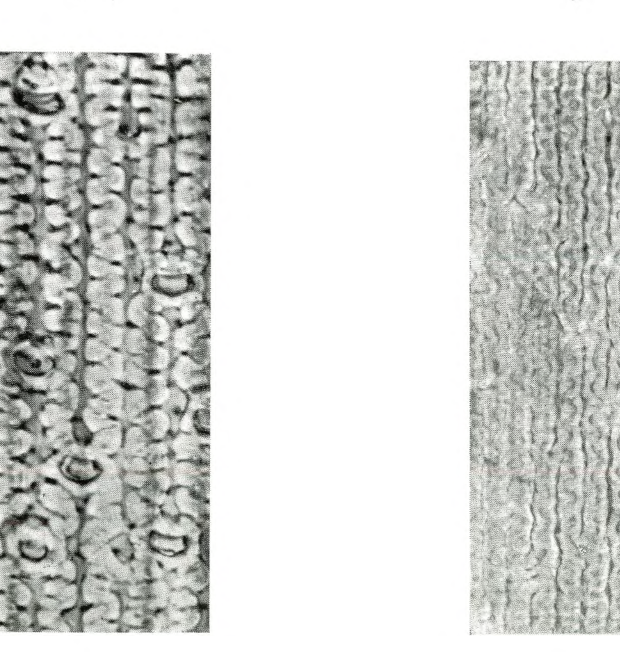
REEDS



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Fig. 1.—Parts of roots and stems of *Ceruana pratensis* (Forsk.) identified anatomically. *From a basket-coffin.* The stems are devoid of leaves and inflorescenses; about 1/2 natural size.

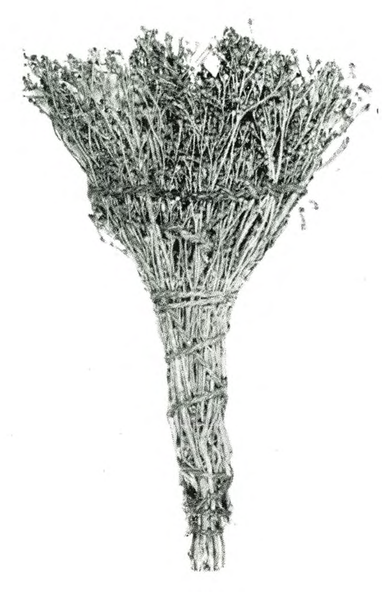
Fig. 2.—*Modern* broom of *Ceruana pratensis* plants tied with a rope of date palm fibres; about 1/6 natural size.

Fig. 3.—Epidermal tissue of *Juncus arabicus* (Lam.) culm (ancient) (much enlarged). Note the thick-walled epidermal cells surrounding each stoma.

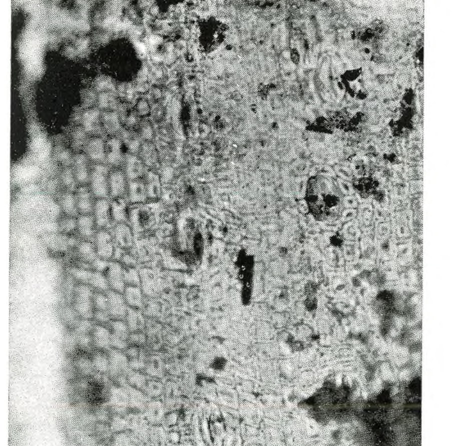
Fig. 4.—Epidermal tissue of *Juncus acutus* (L.) culm (modern) (much enlarged).
The epidermal cells surrounding each stoma are uniform with the other epidermal cells.



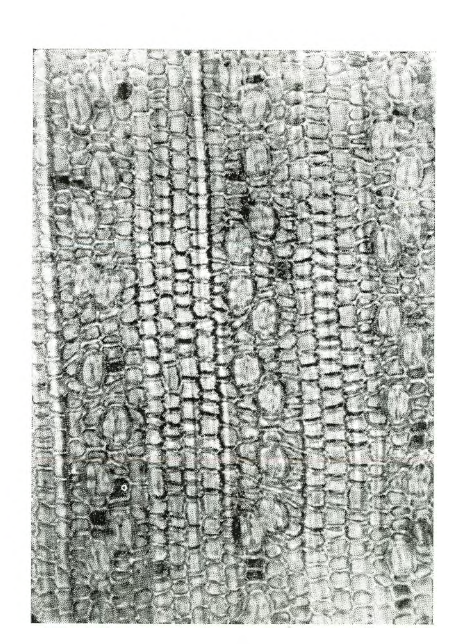
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Fig. 1.—*Cyperus papyrus* (L.) growing in a pool in the Zoological Gardens at Giza, about $^1/_{50}$ natural size. Photo by Prof. T. M. Tadros.

Fig. 2.—Top part of an adult haulm of *Cyperus papyrus* showing the branch segments and foliage leaves forming a crown, about $^1/_6$ natural size. Photo by Prof. T. M. Tadros.

Fig. 3.—Epidermal tissue of the middle region of a (modern) haulm of *Cyperus papyrus*. Note the stomatal rows alternating with rows of ordinary epidermal cells (much enlarged).

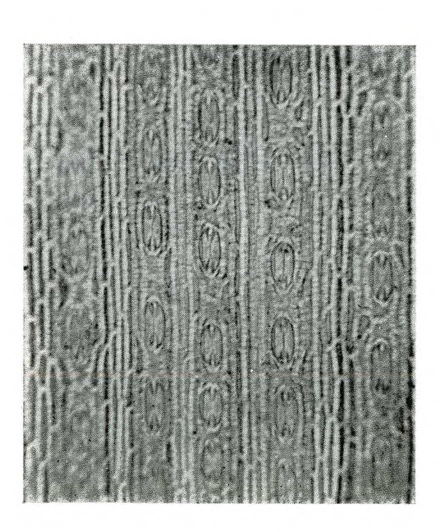
Fig. 4.—Epidermal tissue of a part of an (*ancient*) haulm of *Cyperus papyrus*. Note the same arrangement as in the modern specimen (much enlarged).



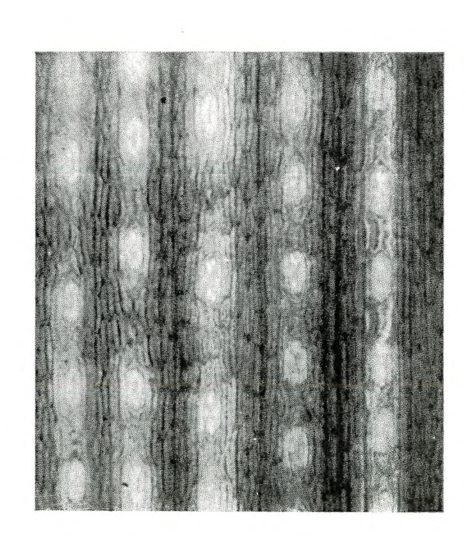
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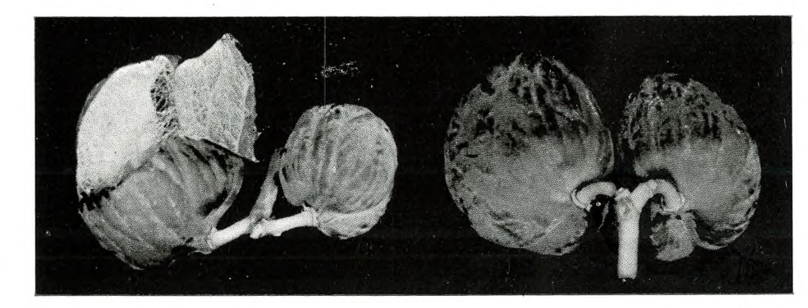
Fig. 1.—Young *modern* fruits of *Calotropis spp.* cut lengthwise. The hairs are surrounding the seed found in rows, about 1/2 natural size.

Fig. 2.—Yound *modern* fruits of *Calotropis spp.* showing the peduncle and two pedicels, about 1/2 natural size.

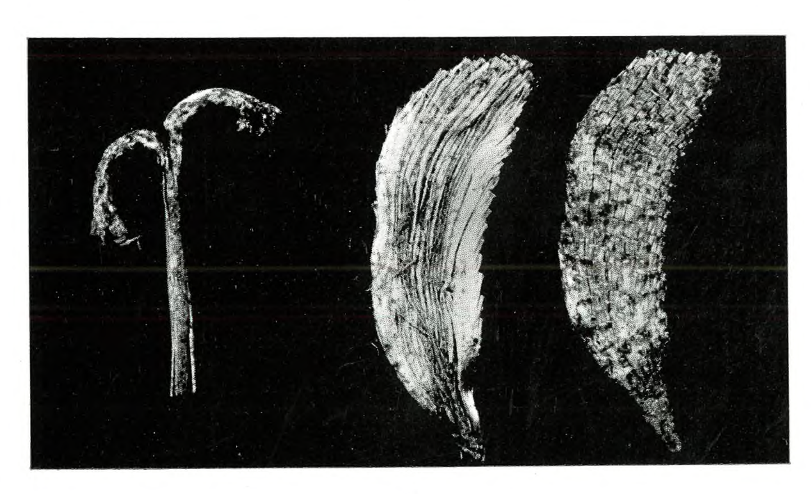
Fig. 3.—Mature *ancient* fruit of *Calotropis* cut lengthwise to show its outer and inner surfaces. Note the arrangement of the hairs in tiers. On the left side is shown the peduncle and two pedicels, about 1/2 natural size. The fruit with its peduncle was found in Helwan excavations.



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2



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PRELIMINARY NOTE ON THE MEASURES OF EMISSION CORONAL LINES AT THE TOTAL SOLAR ECLIPSE OF 25 FEBRUARY 1952

OBSERVED BY

DR. B. LYOT AND DR. M. K. ALY [1]

BY

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HELWAN OBSERVATORY

The Egyptian mission for the total solar eclipse of 25th February 1952 at Khartoum has undertaken among its program, this present work which was suggested by the Late Dr. Lyot of Meudon arranged and observed jointly with Dr. M. K. Aly of Helwan. For this purpose two spectrographs were designed for observing the emission coronal lines close to the sun's limb over the whole range of spectrum from λ 6900 to λ 3100. A short account on the program is followed by a description of the plates obtained and the wavelength measurements of all the coronal lines seen on the plates. Beside most of the previously discovered emission lines observed at earlier eclipses, there are about 16 new lines observed in this occasion.

I. INTRODUCTION

Our program and the description of the equipment used have been published by the auther in The Observatory Magazin (1) and have been included in the description of the general program of the Egyptian

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[1] Communication présentée en séance du 7 décembre 1953.

eclipse expedition in the *Bulletin de l'Institut d'Egypte* (2) by Dr. M. R. Madwar. However, a brief introduction to the observational program will not be out of place here.

The origin of the emission lines of the solar corona is one of the most important problems which deserves careful investigation.

It has not yet been possible to obtain these radiations in the laboratory, but the Physicist Edlén (3) attributed their existence to very highly ionised atoms of iron, nickel and calcium, which have lost between 9 to 14 of their electrons under extremely low pressure. The calculated wave lengths given by Edlén for these lines were generally in fairly good agreement with those in the corona of the sun.

One should expect according to Edlén's theory that, when comparing two coronal lines, their intensity variations all round the sun could be similar if the ionisation potential of the corresponding ions, is nearly the same, and in the case of very different ionisation potential, the intensity variations, would be different.

Such expectations have been confirmed (4) for the radiations in the green, red, and infra-red spectrum, from a number of plates obtained with a coronagraph at the Pic-du-Midi Observatory not during an eclipse. These radiations could be classified in three groups, each behaving in a particular way. One group contains the red and infra-red lines λ 6374, λ 7892, the second contains the yellow line λ 5694 alone and the third contains the green line λ 5303 together with the remaining observed lines. The lines in the blue, violet and ultra-violet with the exception of λ 3388 being very strong, cannot be observed with the coronagraph outside an eclipse as they are always blended with the strongly scattered solar light.

The program was thus arranged to obtain spectra of the inner corona, enabling us to compare the intensity distribution of lines of wave lengths shorter than λ 5000, with some lines in the previously mentioned groups, in particular with the red line λ 6374, the yellow line λ 5694 and the green line λ 5303.

The spectrographs designed are of reasonably high dispersion; about 7 A°/mm. in the green for the glass spectrograph and about 4 A°/mm near H and K for the quartz.

II. OBSERVATIONS OF THE ECLIPSE

We aimed at the study of the emission lines in the inner part of the solar corona. The slits of the spectographs were designed to give circular lines all round the sun at a distance of about one minute of arc from the solar limb. But because of an unforseen error due to differences in letter designation for the magnitude of the eclipse between the Nautical Almanac or the American Ephemeris and the Annual Report of the Bureau des Longitudes, the magnitude of the eclipse is given as 1.036 in the first two and as 1.018 in the French Almanac. The last value was the one we used in our calculations for the design of the instruments in Paris and thus we found the diameter of the disc of the moon will be slightly greater than the designed diameters of the slits, which meant that they will be covered by the disc of the moon during the eclipse. This was only discovered the night before the eclipse and it was too late to make any major alterations. We found it was simplest to change the position of the two correcting lenses in front of the slits by moving them further away from the slits on their mounting. Consequently, the sun's image grew smaller and hence light from parts further out in the corona (about 2 minutes of arc) was observed.

The two spectrographs are rotatable around the collimator axes, and by turning them about 115 degrees from the horizontal plane, the direction of the dispersion was rendered parallel to the sun's equator.

III. THE PLATES

The spectrograms (plate I) : the resulting spectrum on the photographic plates from one exposure on each spectograph was composed of 2 spectra one below the other, the lines in each are in the form of semicircles corresponding to each side of the sun. The middle parts of every spectral line were of 0° latitude *i. e.* the equator of the sun was represented on the spectrum by the middle line along the dispersion. The widths of the spectra on the photographic plates were about eleven millimeters. Prints from the original plates enlarged three times are given in plate I.

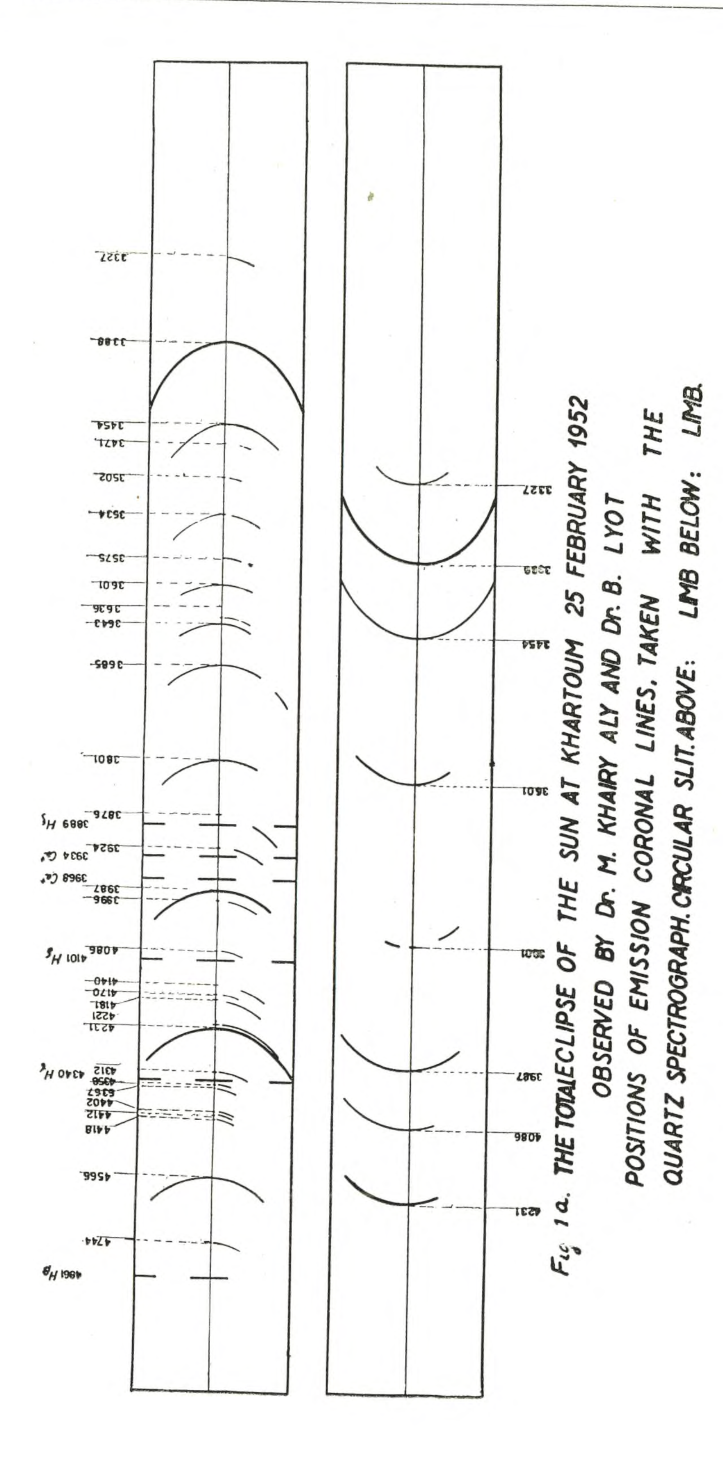


Fig 1 a. THE TOTAL ECLIPSE OF THE SUN AT KHARTOUM 25 FEBRUARY 1952 OBSERVED BY Dr. M. KHAIRY ALY AND Dr. B. LYOT POSITIONS OF EMISSION CORONAL LINES, TAKEN WITH THE QUARTZ SPECTROGRAPH. CIRCULAR SLIT. ABOVE: LIMB BELOW: LIMB.

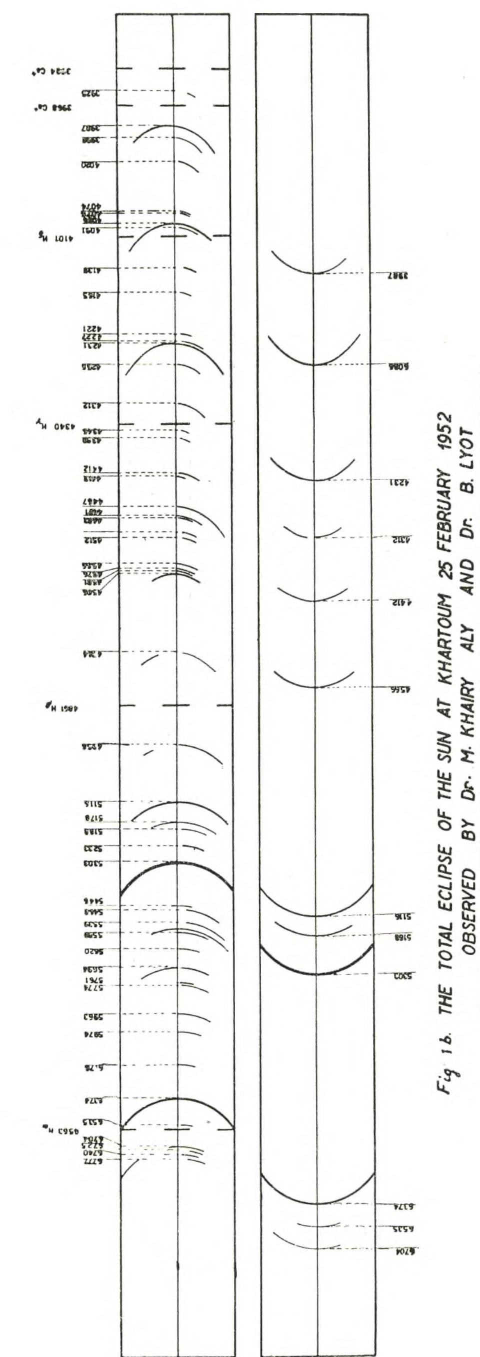


Fig 1 b. THE TOTAL ECLIPSE OF THE SUN AT KHARTOUM 25 FEBRUARY 1952 OBSERVED BY Dr. M. KHAIRY ALY AND Dr. B. LYOT POSITIONS OF EMISSION CORONAL LINES, TAKEN WITH THE GLASS SPECTROGRAPH. CIRCULAR SLIT ABOVE: LIMB BELOW: LIMB.

The plates obtained were four, two for the solar corona taken during the totality and other two taken the day before the eclipse (table I). The first plate : on the glass spectrograph the exposures obtained were in the order 1s., 5s., 30s., 90s. and 10s., to ensure obtaining different exposures if one misses the beginning or the end of totality. A 2s. exposure was also planned to be taken after the 10s. but it was missed for shortage of time at the end.

TABLE I

Plates	Spectrograph	Exposure in seconds	Spectra	Date
(1) Astra III	Glass	90, 30, 10, 5, 1.	Corona	25 Feb. at 9 h. 15 m.
(2) Superfulger (Effet Raman)	Quartz	90, 30, 10, 5, 2, 1,	Corona	25 Feb. at 9 h. 15 m.
(3) Astra III	Glass	90, 10, 1. with density sheets 27, 9, 3. without density sheets	Sun	24 Feb. at 12 h. 00 m.
(4) Superfulger (Effet Raman)	Quartz	90, 10, 1. with density sheets 45, 15, 5. without density sheets	Sun	24 Feb. at 12 h. 45 m.

The spectra of the corona obtained on the glass spectrograph plate were excellent especially on the western side of the sun and very useful for the study of both strong and faint lines from the various exposures. On the spectrum of the other side of the sun only strong lines are seen with no clear traces of prominence lines. Probably this was due to the exposures being interrupted by the moon's shadow covering parts of the slit. The plate was clear from any fog or defect except for my finger prints at the red end of the 30s. exposure at the lower part of the eastern spectrum. This print happened in the process of loading the plates in the hot damp dark room before exposures. The lightly exposed spectra will be of little use for photometry.

On the quartz spectrograph plate exposures were 1s., 5s., 30s., 90s 10s. and 2s. There was slight general fogging due to scattered light from the spath prisms. This was bad in early trials but by special shielding and backing of the prisms and other precautions the scatter was minimised. This fogging will have to be allowed for in the microphotometric reductions. The spectra was very clear and prominence lines as far as λ 2900 were recorded. Naturally at that end lines are out of the zone of best focus. The last coronal line seen clearly on the ultra-violet side was the known λ 3328. On this plate very thin sharp concentric fringes uniform in density and at equal distances of about 3 A° apart appeared, particularly prominent, in the region between λ 3500 to λ 4300. These fringes are seen only on the quartz spectrograph and not on the glass. They are probably caused by the material of the prisms, however, they have no effect on the measurements nor will they have on the photometry as they are of about the same order of magnitude as the plate grain.

Spectra of solar prominences during the eclipse were also recorded on both eclipse plates and their positions and intensities could be studied.

Two other plates were taken with the two spectrographs the day before the eclipse and at nearly the same hour as the eclipse time for the purpose of standardisation. On each plate we have 3 photographs of the solar spectrum of nearly the same exposure times as those of the eclipse plates, namely, 27s., 9s., and 3s. for the glass spectrograph and 45s., 15s., and 5s. for the quartz. Three other exposures of 90s. 10s., and 1s., duration on the same plates of the solar spectrum were taken with gelatin density sheets of steps 0.0, 0.5, 1.0, 1.5 covering one side of each slit (the other side being closed). From these last three exposures solar lines appear with 4 different densities along the lines themselves. Combined measurements from these solar spectra will be used for microphotometric reductions of the eclipse plates.

IV. MEASUREMENTS

Wave lengths of all lines seen on the two spectrograms were measured to the nearest hundredth of a millimeter. Every plate was measured twice separately by both late Dr. Lyot and myself on the Zeiss Blink

Comparator present at Helwan (fig. 2). As there are several exposures on each plate, measurements were effected from every exposure for the lines present on each. The lines appear circular or almost so on the plates and their intensity distribution is different at different position angles round the sun. The appearance of the very faint lines are mostly limited

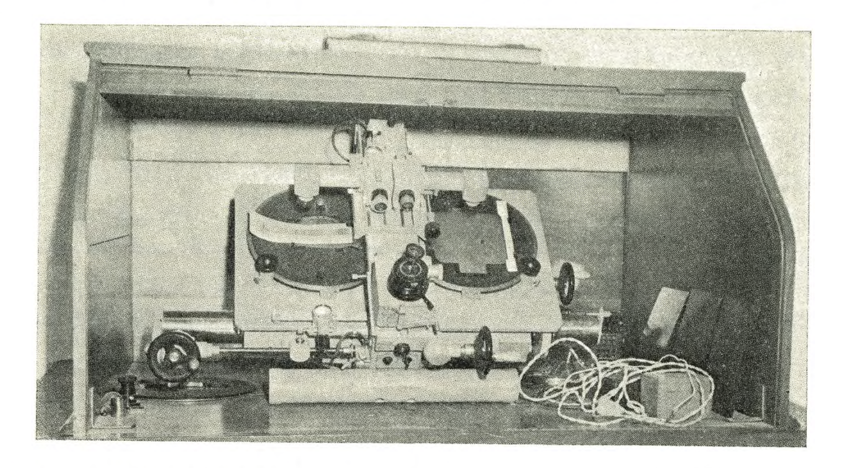


Fig. 2. The Zeiss Blink Comparator at Helwan used for measuring the spectra.

to some parts and not all along the line, but all measurements were reduced to the solar equator.

Later after having made good prints of the original plates enlarged 6 times, it was found that some more lines could be seen on the enlargements which were not visible on the plates. Their wave-length measurements taken from interpolation or extrapolation with very close known lines gave positions accurate within one or two Angstroms.

At this stage the plates were remeasured for wave-length determination and a search for these new lines was effected. This repetition made by the author alone showed a good number of new very faint lines in both plates and enlargements. The presence of some of these lines was confirmed by wave length measurements given for lines observed at earlier eclipses (5). Some alterations were then necessary in the reductions made by Lyot and myself soon after our return from Khartoum. It is seen in the list of table II that some wave-length values taken from the quartz spectrograph are given alongside those of the glass spectrograph

with differences of 2 or 3 Angstroms, also differences between our measurements and those of previous observers listed in column (6) exist. Such measurements are only given here with reserve, to indicate that they might possibly correspond to the same lines, but they could correspond to entirely different lines, and this only existed in the case of very faint or extremely faint lines.

Table II gives a list of the measured wave length of all lines observed in the corona as taken from the western side of the sun only. Column (1) gives serial numbers of all lines observed, (2) wave lengths of lines observed presently by Lyot and Aly, or by Aly alone, (*a*) on the quartz spectrograph (*b*) on the glass spectrograph. In both (2 *a* and *b*) an asterisk indicates that the lines are extremely faint and were not seen on the plates, but only on the prints enlarged 6 times from the original plates, from different exposures. Both sets of lines were listed such that wave length measures for the same line lie alongside with a brace on the left to indicate that it is the same line seen on both spectrograms.

Column (3) gives a general description of the lines. The following system has been found convenient in specifying the degree of surety as regards the presence of lines, and their general appearance : certain (cert.), followed by almost certain (al. cert.), rather certain (rath. cert.), rather doubtful (rath. doubt.), doubtful (doubt.) very doubtful (v. doubt.). For the brightness, the descriptions : very strong (v. strong) followed by strong (strong), faint (f.), very faint (v. f.), and extremely faint (extr. f.) are given. For the general appearances : the intensities vary along the lines and for a faint or an extremely faint one, it is only visible at very limited parts along its length anywhere near or far from the equator but the majority of these are found within a small belt below the equator. For such description it was found enough at this stage to describe the lines as : extended (ext.), when seen on more than half the length of the circular trace, followed by rather extended (rath. ext.), not much extended (not. m. ext.), and not extended (not ext.) when seen only at one particular position.

Column (4) gives the weights (α, β, γ) obtained from our observations and column (5) gives the approximate intensities estimated by the eye from enlargements, taking the intensity of the line λ 5303 as 100.

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
	(a)	(b)						
1	3326.7	—	Cert., strong, not ext., fuzzy	α	7	3328	G., M.	L., A.
2	3388.0	—	Cert., v.strong, ext., broad.	α	65	3388	G., M.	L., A.
3	3454.2	—	Cert., v.strong, ext.	α	15	3454	G., M.	L., A.
4	3471.0	—	Cert., extr.f., not m.ext.	α	2	New	—	A.
5	*3502	—	Al.cert., extr.f., not ext.	β	—	»	—	A.
6	3533.5	—	Cert., f., ext.	α	12	»	—	L., A.
7	3574.7	—	Rath.cert., extr.f., rath.ext.	γ	—	»	—	L., A.
8	3600.9	—	Cert., strong, not m.ext.	α	15	3601	G., M.	L., A.
9	3604.9	—	Rath.cert., v.f. rath.ext.	γ	—	New	—	A.
10	3636.5	—	Rath.cert., extr.f.	γ	—	»	—	A.
11	3642.8	—	Cert., strong, rath.ext.	α	11	3643	G.	L., A.
12	3685.0	—	Cert., v.f., rath.ext.	α	4	New	—	A.
13	*3750	—	Doubt., extr.f., rath.ext.	—	—	»	—	A.
14	*3784	—	V.doubt., extr.f., rath.ext.	—	—	»	—	A.
15	3801.2	—	Cert., strong, rath.ext.	α	12	3801	G., M.	L., A.
16	*3870 —	— 3869.8	Doubt., extr.f., not m.ext. Rath.doubt., extr.f.	—	—	New	—	A.
17	*3876 —	— 3876.2	Rath.cert., extr.f., rath.ext. Doubt., extr.f., not m.ext.	β	—	»	—	A.
18	*3892	—	Doubt., extr.f.	—	—	3892	T.	A.
19	—	3910.7	Rath.cert., extr.f.	γ	—	New	—	A.
20	*3924 —	— *3925	Rath.cert., v.f., rath.ext. Rath.cert., extr.f., rath.ext.	β	—	»	—	A.
21	*3949	—	V.doubt., extr.f., not.ext.	—	—	»	—	A.
22	*3956 —	— 3955.4	Doubt., extr.f., not ext. Rath.cert., extr.f., not ext.	γ	—	»	—	A.
23	*3973 —	— *3973	Doubt., extr.f., ext. Doubt., v.f., rath.ext.	—	—	»	—	A.
24	3987.7 —	— 3987.0	Cert., strong, ext. Cert., strong, ext.	α	25	3987	G., M.	L., A.
25	3996.0 —	— 3998.0	Rath.doubt., v.f., rath.ext. Cert., v.f., rath.ext.	α	3	New	—	L., A.
26	—	4020.3	Al.cert., extr.f., rath.ext.	β	—	»	—	A.
27	—	4037.7	Rath.cert., extr.f., rath.ext.	γ	—	»	—	A.
28	—	4059.7	Rath.doubt., extr.f.	—	—	4056	M.	A.
29	—	4067.4	Rath.doubt., v.f., not m.ext.	—	—	New	—	L., A.
30	—	4069.8	Rath.doubt., extr.f., not m.ext.	—	—	»	—	A.
31	—	4074.0	Cert., extr.f., not ext.	α	1	»	—	A.

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
	(a)	(b)						
32	—	4074.8	Rath.cert., extr.f., not ext.	γ	—	New	—	A.
33	4086.2 —	— 4086.0	Cert., strong, not m.ext. Cert., strong, not m.ext.	α	10	4086	G., M.	L., A.
34	—	4091.1	Rath.cert., extr.f., not m.ext.	γ	—	New	—	A.
35	—	4094.7	Doubt., extr.f.	—	—	»	—	A.
36	—	*4105	Rath.doubt., extr.f.	—	—	»	—	A.
37	—	4111.3	Rath.doubt., extr.f.	—	—	»	—	A.
38	—	4121.9	Doubt., extr.f., not ext.	—	—	»	—	A.
39	—	4123.8	Doubt., extr.f., not ext.	—	—	»	—	A.
40	*4140 —	— 4138.6	Al.cert., v.f., rath.ext. Rath.cert., extr.f.	α	2	»	—	A.
41	—	4157.1	Doubt., extr.f., ext.	—	—	»	—	A.
42	—	4165.3	Cert., extr.f., not ext.	α	4	»	—	A.
43	*4170 —	— *4170	Al.cert., v.f., rath.ext. Rath.doubt., extr.f.	β	—	4170	M.	A.
44	4181.2	—	Al.certain, v.f., rath.ext.	β	—	New	—	A.
45	*4184 —	— *4184	Doubt., v.f. Doubt., extr.f., ext.	—	—	4184	T.	A.
46	—	4187.7	Doubt., extr.f., not m.ext.	—	—	New	—	A.
47	*4204	—	Doubt., extr.f., not m.ext.	—	—	»	—	A.
48	*4221 —	— *4221	Al.cert., v.f., ext. Rath.cert., extr.f., not ext.	α	3	»	—	A.
49	—	4227.2	Rath.cert., extr.f., ext.	γ	—	4228	T.	A.
50	4232.1 —	— 4231.9	Cert., v.strong, ext., uniform. Cert., strong, ext.	α	35	4231	G., M.	L., A.
51	—	*4252	Doubt., extr.f., not ext.	—	—	New	—	A.
52	—	4256.4	Cert., v.f., broad, rath.ext.	α	2	»	—	A.
53	—	4267.4	Rath.doubt., extr.f., broad, ext.	γ	—	»	—	A.
54	—	4282.1	Doubt., extr.f., broad, not ext.	—	—	»	—	A.
55	4312.0 —	— 4312.1	Al.cert., v.f., rath.ext. Cert., v.f., broad., ext.	α	8	4311	D., T.	A.
56	—	4331.4	V.doubt., extr.f.	—	—	New	—	A.
57	—	4344.7	V.doubt., extr.f.	—	—	»	—	A.
58	*4349 —	— 4350.6	Rath.cert., extr.f., not ext. Al.cer., v.f., rath.ext.	α	3	4349	Ed.	A.
59	4358.2 —	— 4358.1	Cert., v.f., broad, not ext. Cert., f., fairly uniform.	α	6	4359	T.	L., A.
60	—	4363.2	Al.cert., extr.f., not ext.	β	—	New	—	A.

(1)	(2) (a)	(2) (b)	(3)	(4)	(5)	(6)	(7)	(8)
61	*4367 —	— *4367	Rath.doubt., extr.f., not ext. Rath.doubt., extr.f., not ext.	—	—	New	—	A.
62	*4376 —	— 4376.3	Doubt., extr.f., not m.ext. Rath.doubt., extr.f., rath.ext., probably chromospheric.	γ	—	»	—	A.
63	*4402	—	Rath.cert., extr.f., not ext.	γ	—	»	—	A.
64	4412.0 —	— 4413.2	Cert., f., not ext. Cert., f., rath.ext.	α	10	4412	Dunham	L., A.
65	*4418 —	— *4418	Rath.cert., extr.f., not ext. Rath.cert., extr.f., not ext.	β	—	New	—	A.
66	—	4422.6	Rath.doubt., v.f., rath.ext.	—	—	»	—	A.
67	—	4428.4	Doubt., extr.f., probably chromospheric.	—	—	»	—	A.
68	4455.7	—	V.doubt., extr.f.	—	—	»	—	A.
69	—	4466.9	Al.cert., v.f., broad.	β	—	»	—	A.
70	—	4474.6	Rath.doubt., extr.f., rath.ext.	γ	—	»	—	A.
71	—	4481.0	Rath.cert., extr.f., rath.ext.	γ	—	»	—	A.
72	4484.1 —	— 4482.6	Doubt., extr.f. Rath.cert., extr.f., rath.ext.	β	—	»	—	A.
73	—	4490.2	Doubt., extr.f., not ext.	—	—	»	—	A.
74	—	4494.4	Doubt., extr.f., not ext.	—	—	»	—	A.
75	*4504 —	— *4504	Al.cert., extr.f., rath.ext. Al.cert., extr.f.	α	3	»	—	A.
76	—	*4512	Al.cert., extr.f., broad.	β	—	»	—	A.
77	—	4525.0	Doubt., extr.f.	—	—	»	—	A.
78	—	4549.5	Doubt., extr.f.	—	—	»	—	A.
79	—	4558.4	Doubt., extr.f.	—	—	»	—	A.
80	4566.1 —	— 4566.3	Cert., f., ext. Cert., f., ext.	α	15	4567	G., M.	L., A.
81	—	4576.5	Rath.cert., extr.f.	γ	—	New	—	L., A.
82	4580.1 —	— 4581.8	Al.cert., v.f., not ext. Doubt., extr.f.	α	1	»	—	A.
83	4587.5 —	— 4585.7	Al.cert., v.f., not m.ext. Cert., v.f.	α	6	4586	D., T.	L., A.
84	*4617	—	Rath.doubt., v.f., not ext.	—	—	New	—	A.
85	—	4658.5	V.doubt., extr.f.	—	—	»	—	A.
86	—	4677.2	Doubt., extr.f., rath.ext.	—	—	»	—	A.
87	*4729	—	Doubt., extr.f., not ex.t	—	—	»	—	A.
88	*4744 —	— *4744	Cert., v.f., rath.ext. Rath.doubt., v.f.	α	3	»	—	A.

(1)	(2) (a)	(2) (b)	(3)	(4)	(5)	(6)	(7)	(8)
89	—	*4956	Cert., extr.f., ext.	α	2	New	—	A.
90	—	5114.8	Cert., strong, uniform.	α	30	5117	G., M., T.	L., A.
91	—	5121.4	Rath.doubt., extr.f., rath.ext.	—	—	New	—	A.
92	—	*5178	Al.cert., extr.f., ext.	β	—	»	—	A.
93	—	5188.5	Al.cert., extr.f., not ext.	β	—	»	—	A.
94	—	5232.9	Al.cert., extr.f., not ext.	β	—	»	—	A.
95	—	5251.0	Rath.cert., extr.f., not ext.	γ	—	»	—	A.
96	—	5279.0	Doubt., extr.f., ext.	—	—	»	—	A.
97	—	5301.9	Cert., v.strong, ext.	α	100	5303	G., M., L.	L., A.
98	—	5311.8	Doubt., extr.f.	—	—	New	—	A.
99	—	5335.4	Doubt., extr.f.	—	—	»	—	A.
100	—	5367.5	Doubt., extr.f.	—	—	»	—	A.
101	—	5428.0	Rath.doubt., extr.f., broad.	—	—	»	—	A.
102	—	5446.0	Cert., extr.f.	α	3	»	—	L., A.
103	—	5454.7	Doubt., extr.f., not ext.	—	—	»	—	A.
104	—	5459.9	Doubt., extr.f., not ext.	—	—	»	—	A.
105	—	*5468	Rath.cert., v.f., fine, ext.	α	2	»	—	A.
106	—	*5510	Rath.cert., extr.f., rath.ext.	γ	—	5509	L.	A.
107	—	5539.5	Cert., v.f., uniform.	α	8	5536	D., G., T., M.	L., A.
108	—	5558.6	Cert., extr.f.	α	1	New	—	A.
109	—	*5583	Rath.doubt., extr.f., not ext.	—	—	»	—	A.
110	—	5620.1	Al.cert., extr.f., rath.ext.	β	—	5624	S.	A.
111	—	5643.4	Doubt., extr.f., not ext.	—	—	New	—	A.
112	—	5678.4	Rath.doubt., extr.f.	—	—	»	—	A.
113	—	5693.7	Cert., v.f.	α	7	5694	L.	L., A.
114	—	*5747	Doubt., extr.f., not ext.	—	—	New	—	A.
115	—	*5761	Rath.doubt., extr.f., rat.ext.	—	—	»	—	A.
116	—	*5774	Al.cert., extr.f.	β	—	»	—	A.
117	—	5902.7	Rath.cert., v.f., not ext.	γ	—	»	—	A.
118	—	5914.8	Doubt., extr.f., broad.	—	—	5912	M.	A.
119	—	5955.5	Rath.cert., extr.f., not ext.	γ	—	New	—	A.
120	—	5963.8	Rath.doubt., extr.f., not ext.	—	—	»	—	A.
121	—	5974.3	Al.cert., v.f.	β	—	»	—	A.
122	—	*6002	Rath.doubt., extr.f., broad, not ext.	—	—	»	—	A.
123	—	6072.5	V.doubt., extr.f.	—	—	»	—	A.
124	—	*6176	Rath.cert., v.f., rath.ext.	γ	—	»	—	A.

(1)	(2) (a)	(2) (b)	(3)	(4)	(5)	(6)	(7)	(8)
125	—	6286.9	Rath.doubt., extr.f., rath.ext.	—	—	New	—	A.
126	—	6374.2	Cert., v.strong, ext.	α	80	6374	M.	L., A.
127	—	6490.3	Doubt., v.f., ext., broad.	—	—	New	—	A.
128	—	6535.4	Rath.cert., v.f., ext., broad.	γ	—	6534	S.	A.
129	—	6599.6	V.doubt., extr.f.	—	—	New	—	A.
130	—	6633.8	Doubt., extr.f.	—	—	»	—	A.
131	—	6666.1	Doubt., extr.f.	—	—	»	—	A.
132	—	6672.1	Doubt., v.f., rath.ext.	—	—	»	—	A.
133	—	6702.8	Cert., v.f., not m.ext.	α	10	6702	G., L., M.	L., A.
134	—	*6725	Rath.cert., extr.f., not ext.	γ	—	New	—	A.
135	—	*6740	Al.cert., v.f., rath.ext.	β	2	»	—	A.
136	—	*6777	Al.cert., v.f., rath.ext.	β	—	6776	M.	A.
137	—	6807.2	Doubt., v.f., rath.ext.	—	—	New	—	A.
138	—	*6860	Doubt., v.f., rath.ext.	—	—	»	—	A.

Culumn (6) gives wave lengths of coronal lines seen by observers at previous eclipses taken from other references (5).

Column (7) gives initials of previous observers D = Davidson, E = Edlén, G = Grotrian, L = Lyot, M = Menzel, S = Sakignti and T = Tanaka.

Column (8) gives initials of present observers L = Lyot and A = Aly.

The Balmer series and the H and K lines of ionised calcium as well as a number of metallic solar lines have served as our landmarks, these together with some of the well known coronal lines, were very useful in forming the correction curve of $\Delta\lambda$. The dispersion is so small near the Hα end of the visible spectrum and the $\Delta\lambda$ curves are not determinate, probable errors of about $\pm$ 3 A° are present.

In general there is very close agreement in the known lines between present and previous wave-length measurements. With the exception of lines near the red end, discrepancies have not exeeded 1.0 A° except in rare cases namely for the lines λλ 4056, 5517, 5536, 5624, 5912 where the discrepancies reached 2 or 3 Angstrom units. The diagrams given in figures I *a* and I *b*, show with sufficient accuracy the positions of most of the observed lines on both limbs together with their wave lengths.

V. DISCUSSION AND CONCLUSION

We have obtained with our equipment recordings of 138 emission coronal lines of all categories; 78 lines of which, are graded certain, almost certain or rather certain and weighted α, β or γ. The rest fall under the grade doubtful. Only 37 of these are certain (α), 21 of which have been observed in previous eclipses and the remaining 16 are certain lines not known to have been observed before. The existence of the previously observed lines is thus checked and the intensity variations at different position angles could be studied for the strong ones. It must be mentioned that some of the faint lines previously observed have been seen here with some doubt as shown in the list and some others have not been found.

As for the photometric values, about 16 lines in the whole range of the observed spectrum will be of value for studying their intensity distribution.

We have also succeeded in recording spectra in the blue and the ultra-violet which were beyond the scope of the coronagraph. The strong line λ 3388 was beautifully recorded on more than one exposure and all round the sun (60° north and 60° south of the equator). As it has been observed previously with the coronagraph it will thus serve as a very good standard for comparing the intensity distribution of other lines in this region. The only coronal line that could be studied beyond that in the ultra-violet is the known line λ 3327, which appears on the western limb just at a region of 20° below the equator and on the eastern limb it shows some 25° north and 25° south.

On the other side of λ 3388 in the blue there are a number of nicely recorded lines, most of which could be used for photometric study, namely the known lines λλ 3454, 3601, 3801, 3987, 4086, 4231. The three lines λλ 3987, 4086, 4231 are recorded on both spectrograms, more clearly so on the quartz. The faint new line in this region namely λ 3534 easily seen to about 25° north and 25° south on the western limb, could be studied photometrically. The rest of the new

lines in this region appearing in the list, though seen on the spectrograms, are below the intensity desired for the microphotometric investigation. In the green, in the vicinity of the strongest line recorded in all the spectrum (λ 5303), the two lines λ 4566 and λ 5115 could be studied photometrically. In the red we have, near the very strong line λ 6374 seen all round the sun, the line λ 6703 which could possibly be studied.

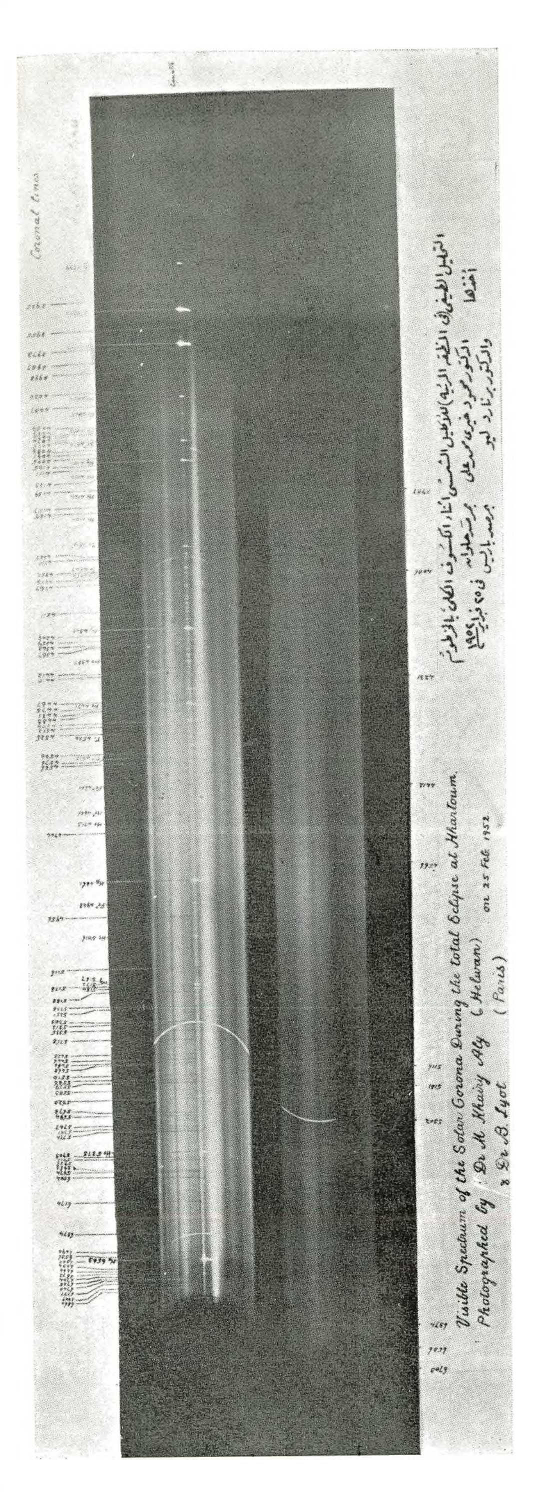
In this connection it is my pious duty to mention with the deepest regret the untimely death of the late Dr. Bernard Lyot, whose loss was felt by astronomers all over the world. It has been a great honour and pleasure to work under the direction and in collaboration with this eminent astronomer.

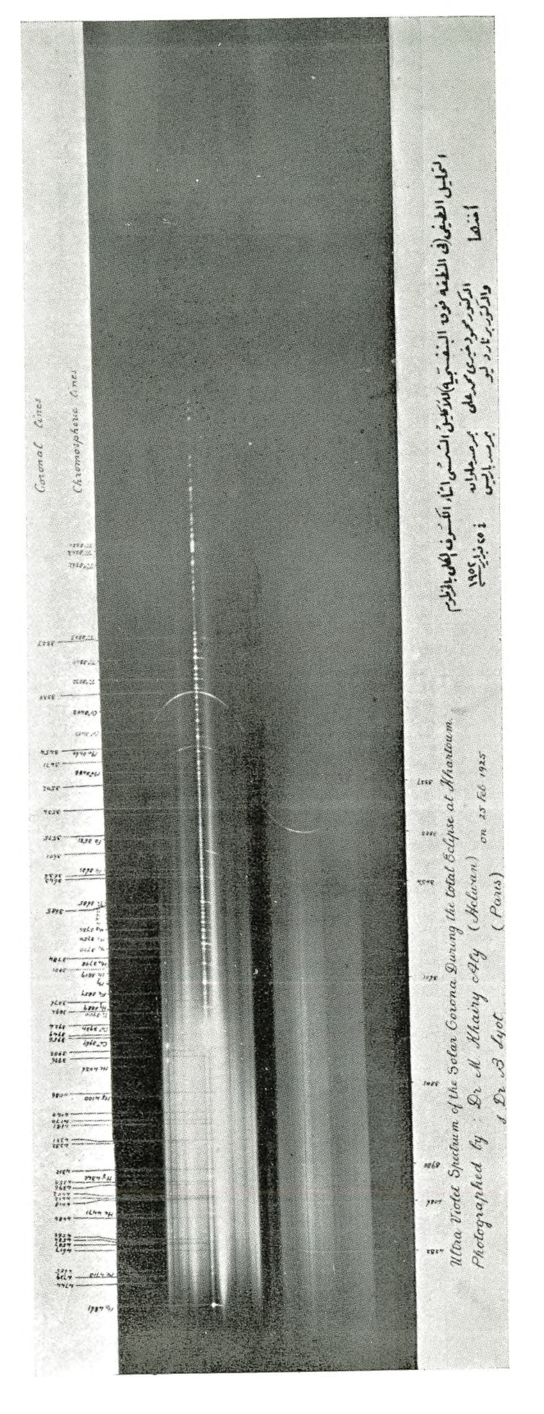
The program of this work was arranged jointly during my stay in Paris, and was carried out at Khartoum, in a most cordial and amicable atmosphere. To M. H. Grenat and his staff at the Meudon Observatory for building the equipment we are also grateful. It is a particular pleasure for the author to thank Mrs. B. Lyot for her help in giving time signals during the eclipse. I am also indebted to the Director and the staff of the Meudon Observatory for the loan of the equipment.

Finally, the author wishes to acknowledge his indebtedness to Prof. M. R. Madwar for the introduction of the whole expedition in Egypt, for his efforts in facilitating all the difficulties to carry out such a program and for his valuable checking and criticism.

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THE STRATIGRAPHY AND GEOLOGY OF THE DISTRICT BETWEEN THE NORTHERN AND SOUTHERN GALALA PLATEAUS (GULF OF SUEZ COAST, EGYPT)[1]

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Abstract : Jurassic rocks, hitherto mapped as Carboniferous on the Geological Survey map, are justifiably identified to outcrop as Bathonian in several places of the District between the sea-front and the south eastern escarpments of the North Galala plateau. This is a southerly extension of rocks of this age, after they disappear, for about 40 kms., under the younger formations of the Galala plateau. The deposition of the unfossiliferous Nubian series, so extensively developed in the district, was effected in five episodes : Cenomanian-Jurassic, Jurassic-Carboniferous, Senonian-Carboniferous, Inter-Carboniferous and Pre-Carboniferous.

Carboniferous rocks, now confined to the hills of the central parts of Wadi Araba, are assigned to the base of the Upper Westphalian or Moscovian.

ACKNOWLEDGMENTS

I am indebted to Sir Arthur E. Trueman for reporting on some lamellibranchs which I had sent on to him, to which he suggested a Jurassic age, and to Dr. L. R. Cox for identifying these as *Homomya inornata* (Sowerby), agreeing with Sir Trueman on their age. Professor I. Farag of the Cairo University was so helpful by letting me compare the corals of the now-considered area with his rich collection of Jurassic corals from Egypt, which he will make the base of a joint work with Alloiteau.

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[1] Communication présentée en séance du 8 février 1954.

I have also pleasure in thanking Dr. Yehia Anwar, of the Alexandria University, for the petrographical report on the slides and specimens which I passed on to him and which is embodied here in the text within the section of volcanic intrusions.

CONTENTS

I. Introduction

Previous work :

The present district arose the interest of several workers as early as 1850, when Hekekyan Bey reported on the strata cut through in excavating for coal in Wadi Araba, and on no organic evidence declared the presence of Lias, without even locating the position of his shaft, under some 31 feet of surface alluvium and Chalk formation.

In 1864, Figari Bey revealed the presence of Lias in three places in the Southern Galala near the monasteries of St. Antony and St. Paul.

Schweinfurth, 1885, 1887, devoted two lengthy reports on the district recording the first discovery of Carboniferous formations in Egypt. Since that important discovery and various geological works, (Walther 1890, Schellwien 1894, Fourtau 1900, Blanckenhorn 1900 and 1921, Ball 1910, Greco 1915, Sadek 1926, Andrew 1937, Cuvillier 1937, Arkell 1951, and Shata 1953), have devoted detailed chapters or passing remarks on something or the other in the district, contributing thus with much valuable information to the geology and palaeontology of the area.

Object of present work :

Inspite of all this accumulated literature on the district, there are still certain substantial points that need clarification or completion, and the object of the present work is to :

1. Record the presence of Jurassic exposures, appearing to outcrop on large tracts of the area, though hitherto mapped as Carboniferous.

2. Clear the stratigraphical confusion over the Nubian series and the Carboniferous.

3. Provide a 1:100,1000 geological map for the district.

4. Explain the tectonic movements and the accompanying volcanic activity.

5. Give a clear picture of the geological history of the area.

II. Topography

The district forming the subject of the present report is a more or less quadrangular area, lying between lats. 29°0'.—29°25'. and Longs. 32°20'—32°40'. approximately. One side of the quadrangle is occupying about 40 kms. of the western coast of the Gulf of Suez, between Mersa Thelemet in the south and Ras Abou Darag in the north. The opposite side is across Wadi Araba about 40 kms. west of Ras Zaafarana (Zaafarana lighthouse). The other two sides of the quadrangle are bound on the north and south by the Northern and Southern Galala Plateaus respectively.

The position of the district is indicated by the shaded part of the following sketch map :

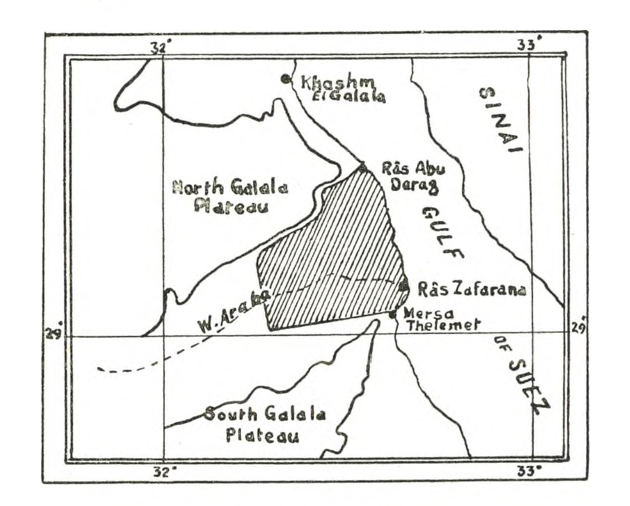


Fig. 1

The main topographic features of this district are relatively low escarpments (maximum height about 300 ms. above sea level), compared with the great heights of the enclosing plateaus of El Galala which have average heights of over 700 ms.

The area is traversed by a large number of drainage lines (Wadis), shedding from either Galala and flowing gently to the sea or forming tributaries of the main drainage line in the district, the Wadi Araba, par excellence, which itself has its watershed the high Cretaceous and Eocene plateaus in the west.

The floors of the wadis, as well as the terraces or the slopes and tops of the hills, are covered by sheets of fanglomerates, particularly thick on the piedmont parts of the wadis, making them in many cases inaccessible for locomotives.

III. Stratigraphy

The geological formations in the district, enclosed in every direction except on the sea-side by the Cretaceous, are of Carboniferous or Jurassic ages or belong to one of the episodes which form the Nubian series and which collectively range from Pre-Cambrian to Senonian.

1. *The Nubian series.*

The Nubian series (or the Nubian sandstones, as they are popularly called, for they are actually mostly sandstones but with intervening bands of clays, shales or grits) have variable lithological characters. Their colour vary from dark brown, dominating, to different shades of pink, red, green and white.

The sandstone grains are angular or subangular, variable in shape and size, mostly siliciously or ferruginously cemented but occasionally with a calcareous or an argillaceous matrix. The Series are in most cases well stratified, occasionally showing false bedding; this together with the character of the grains are indicative of the shallow water facies of the series.

Because throughout the mass of the 'sandstones' the fossils are generally absent or extremely rare, this formation has caused certain stratigraphical confusion.

Masses and beds of this 'sandstones' of very similar nature intervene fossiliferous episodes of definite Carboniferous, Jurassic or Cretaceous ages.

Five episodes can be recognised in these Nubian series :

A. The first of these is represented by 50 to 100 ms. thick sandstones and marls lying under the Carboniferous fossil bearing horizon. Its base is unknown and thus its age can range from Pre-Cambrian to Carboniferous.

B. Following the fossiliferous Carboniferous horizon (limestones, marls and sandstones), comes the second horizon of these Nubian series, some 30 ms. thick ending in a 2 ms. thick black or reddish sandstones with fossil wood belonging to the genus *Araucarioxylon;* and if Schweinfurth's proposal, to put the limit of the Carboniferous at the *Araucarioxylon* layer, is adopted then this second horizon of the Nubian series might be considered as Carboniferous in age.

C. In the southern parts of the district, the fossiliferous Carboniferous layers dipping S. S. W. and S. E. are overlain by a series of unfossiliferous sandstones which occupy all the southern grounds of the district till the Senonian country of the Southern Galala is reached.

D. The fourth of these Nubian horizons is that underlying the Jurassic clays and limestones. It consists of 35 ms. thick, at maximum exposure, of greenish and brownish sandstones, shales and clays.

E. The last of the Series observed in the District are those lying between the Jurassic yellow limestone and the greenish richly fossiliferous Cenomanian marls and clays. These amount to 100 ms. thick of brown and reddish sandstones near the base, becoming constantly whitish upwards, marking thus a fixed horizon at the base of the Cenomanian, which conformably overlies it.

2. *Carboniferous.*

Facies : The fossiliferous Carboniferous layers in the district are mainly of a marine facies, sandstones, shales, marls and limestones. Only a small part of the succession is representing a continental environment during Carboniferous times. These are the 2 ms. thick black or

reddish sandstones with *Araucarioxylon* capping the period's formations.

Fossil contents : The fossils found are neither in great abundance nor in good state of preservation, but many are batterred or stuck crowded on slabs of rocks. They are distributed between the four lithological facies mentioned above, although the crinoidal limestones are the richest, having yielded most of the organic remains. The most frequent and best identifiable of these are the following, arranged as follows according to frequency :

1. *Productus semireticulatus* Mart.; 2. *Productus* cf. *pusillus* Schellw.; 3. *Myalina depressa* De Kon; 4. *Dielasma hastata* (Sow.); 5. *Orthotetes crenistria* (Phillips;) 6. *Spirifer* aff. *mosquensis* Fisch; 7. *Fenestella carinata* M. Coy; 8. *Bellerophon* cf. *tenuifascia* de Kon.

Stratigraphical characters :

On examining G. 171 on the eastern side of a small tributary which opens in Wadi Araba, only about 3 kms. west of the classical Carboniferous area of Rod el Haml, the following section could be made out :

	Approximate thickness in ms.
5. Brown reddish sandstones and sandy clays, unfossiliferous	30
4. Grey caverneous limestone, unfossiliferous	4
3. Greenish soft marls intercalated with many thin crinoidal limestone bands which yielded many fossils, *Productus semireticulatus, Orthotetes crenistria, Myalina depressa,* etc.	5
2. Unfossiliferous brown sandstones	20
1. Unfossiliferous greenish chocolate sandy clays, seen to	2

The total thickness of the formations which can be safely attributed to a Carboniferous age, that is from the top of the first horizon of the Nubian series to the end of the Araucarioxylon sandstone, are the sum of 60 ms. at maximum.

There is a great deal of lateral variation and of change of facies between the different fossiliferous Carboniferous horizons. Even the most constant of these horizons, the crinoidal limestone, was liable for change. In some places it was found to be 2 ms., or thin bands intercalated at short intervals by soft greenish marls, a one metre thick according to

Blanckenhorn and Schweinfurth or even half a metre in other places as measured by Arkell.

The relation between the fossiliferous Carboniferous and the underlying or the overlying Nubian series, is that of perfect conformity. I could not notice the slight unconformity Arkell referred to in his 1951 work, which could be only a local discordance.

Age : The variable ranges of the important fossils of the Carboniferous in the district are here considered before a decision on the age of the formation is attempted, thus :

1. *Productus semireticulatus* and *Orthotetes crenistria,* both have long lives ranging from Lower Carboniferous to the Permo-Carboniferous.

2. *Productus pusillus* is found in the Permo-Carboniferous.

3. *Spirifer mosquensis* is very rare in the C_1^5 or the top zone of the Namurian, and as such it occurs in the Carboniferous formation now considered.

4. Other members of the fauna have wider ranges and cannot be used as stratigraphic markers.

From a consideration of the above mentioned points, a place of the Wadi Araba Carboniferous might be sought at the base of the *Spirifer mosquensis* bed C_2^1 ; of the Russian nomenclature or the base of the Upper Westphalian or Moscovian.

3. *Jurassic.*

The only definite occurrence of Jurassic rocks in Egypt proper, hitherto known, is in the north eastern corner of the Northern Galala, recorded by Sadek in 1926 at Khashm el Galala and by Farag in 1948 at Ras el Abd and Wadi Am Lug.

Figari however claimed the occurrence of marine Lias at three places in the Southern Galala, which he mentioned in his 1864 work. In 1915 Greco reporting on Figari's collection from these localities supported Figari's claim for a Sinemurian in the Southern Galala but only in one of Figari's three localities, namely the Wadi Murakhan near St. Antony monastery, the other two localities he concluded have no fossils indicative of a Liassic age.

Arkell in Jan. 1951 conducted a wide search for Figari's and Greco's alleged Sinemurian, in Wadi Abu Marach and Wadi Bikheit, two northerly tributaries of Wadi Araba running from the Northern Galala, which he believed are the Wadi Murakhan and Wadi der Bakit of Figari, but did not find any Lias and succeeded however in extending for some few kms. north-westwards the outcrops of the Carboniferous system shown on the 1928 Geological Survey map. Arkell thus concludes that the alleged Sinemurian of Figari is not found at all and that « Wadi Murakhan cannot be in Egypt at all but in Italy and that the Gryphaea limestone '*Gryphaea vesicularis*' of Wadi Araba were mixed in Figari's memory with the much similar *Gryphaea arcuata* of the Lias of Italy.»

Shata 1953, stated that Jurassic was recorded in the west of the Gulf of Suez area by the Standard Oil Co. Geologists in Lat. 29°15′ Long. 32°24′.

The present new discovery of Jurassic exposures is among the relatively low hills stretching between the sea front and the south-eastern escarpments of the North Galala plateau (Lats. 29°16′ — 29°23′ and Longs. 32°29′ — 32°34′ approximately).

Facies :

An oscillating sea of shallow water to pelagic depth had deposited the sandstones, clays or marls and limestones of the Jurassic of this district.

The most constant of these horizones is 2-3 ms. yellow hard limestone which stand conspicuous over the multicoloured sandstones or clays and through which it was able to draw the extension of the Jurassic over the district (Plate I, fig. 1).

Fossil contents :

My long search for fossils of this age in 1945 and 1953 was only rewarded by few specimens of the following species :

> *Thamnastraea crateriformis* Gregory ; — *Confusastraea parva* Gregory *Arcaiocoenia sp.* Alloiteau ; — *Rhynconella asymmetrica* Kitchin ; — *Homomya inornata* (Sowerby) ; — *Trigonia pullus* Sowerby ; — *Nucula* cf *variabilis* Sowerby ; — *Ampullina* cf *zetes* d'Orb.

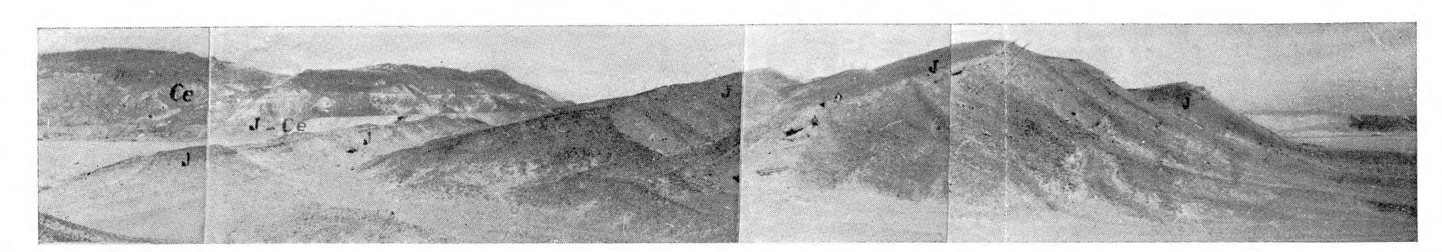


Fig. 1

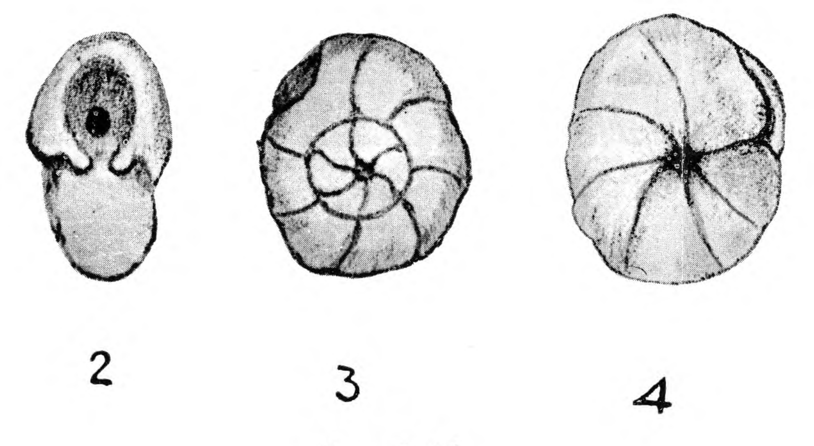


Fig. 2, 3 et 4

STRATIGRAPHICAL CHARACTERS :

A section from a hill (J_4 on the map), about 2 kms. S. W. of Abou Darag lighthouse and heading towards the high escarpment of the Galala plateau, exhibits the stratigraphical relations of the Jurassic in the district as follows :

	Approximate thickness in ms.
7. Greenish Cenomanian marls..................	
6. Brown to reddish and reddish white sandstone, (Jurassic to Cenomanian Nubian)............	135
5. Hard yellow limestone, the type which yielded the corals and *Trigonia pullus*	2
4. Greenish clay with gypseous veins which yielded small lamellibranchs as *Nucula variabilis*	8
3. Ochreous red argillaceous sandstone intercalated with some thin argillaceous beds and a 30 cms. very yellow clayey bed.	10
2. Buff coloured clayey sandstone................	15
1. Greenish or bluish marly clays, seen to	3

The thickness of the fossiliferous Jurassic layers in the district is estimated at some 10-18 ms. thick in places examined. These include the 2-3 ms. invariably yellow limestone horizon which yielded the Homomyas, the Trigonias and the corals and the underlying greenish clays with gypseous veins which have provided a number of small lamellibranchs and a new genus of Rotaliidae. This new foraminifer, which I call *Abou-daragina*, after its type locality Abou Darag, is particularly distinguished by a circular aperture at the base of a cup shaped depression in the middle of the apertural face. This aperture comes near to the aperture of the genus *Eponidella* of Cushman and Hedberg but the present genus is easily distinguished from that Miocene genus by having only one series of ventral chambers, no supplementary series being added on the umbilical portion of the test.

ORDER FORAMINIFERA

Family Rotaliidae

Genus *Aboudaragina* Nakkady

Genotype *Aboudaragina eponidelliformis* Nakkady

Plate I, figs. 2-4

Test of moderate size, trochoid, two whorls are visible on dorsal side and only the seven chambers of the last whorl to be seen on the ventral side. Umbilicus clear. Sutures on both sides are very slightly depressed or run on the surface. Wall calcareous, finely perforate. Aperture circular, at the base of a cup shaped depression that occupies most of the apertural face.

Genotype : Diameter, 0.65 mm., thickness, 0.38 mm.; deposited in the Geology Department, University of Alexandria.

These fossiliferous Jurassic beds lie conformably over the fourth horizon of the Nubian series and are likewise conformably overlain by the last of the Nubian series in the district which separate them from the greenish Cenomanian marls.

Age :

Inspite of the poverty of the fossil assemblage, it is possible to assign an age to the present Jurassic formation. Such forms as *Homomya inornata, Trigonia pullus, Confusastraea parva* and *Thamnastraea crateriformis,* which are the most frequent members of the collection, have a decided Bathonian aspect, and the first three species were already recorded from the Bathonian of Egypt. Also the Nuculas found are identical with those collected by Farag from Ras el Abd.

It is true that *Rhynconella asymmetrica* was reported from the Upper Charee of Cutch and thus has an Oxfordian affinity, while the *Ampullina* is similar to d'Orbigny's species *zetes* from the Callovian of Moghara (Sinai, Egypt), but these do not disprove the Bathonian age which I am inclined to assign to the Jurassic of this district.

If the Bathonian age of these beds is accepted, then it is very probable that the hard yellow limestone 2-3 ms. thick of the present district is a southerly extension, under the great Northern Galala plateau, of the compact limestone-Lower Rhynconella-bed of Khashm el Galala and Ras el Abd to the north.

The shoaling of the sea which came near the end of the Jurassic of Khashm el Galala, Ras el Abd and Wadi Am Lug and which eventually led to the deposition of the Nubian sandstone found under the Cenomanian (Jurassic to Lower Cretaceous according to Farag), this shoaling must had started earlier in the south, in the now-considered district, immediately after the formation of the Jurassic yellow limestone and concordantly deposited over it the last of the Nubian horizons, thus skipping to deposit Jurassic beds analogous to those found between the Lower Rhynconella horizon and the Jurassic-Cretaceous Nubian sandstone of the other end of the Galala plateau.

IV. Geology

1. *Tectonics :*

The configuration of the present district is a result of the action of folding and erosion.

Folding is the predominant element in the tectonics of the area. Minor domal uplifts observed in many places in the district were synchronous with the great anticlinal arch which embraced all the Gulf of Suez area during the early Oligocene-early Miocene times and which ran NW-SE.

Contemporaneous with these tectonic movements and belonging to the same period of volcanicity, are outflowing of lavas or intrusion of dykes observed in many places in the district.

2. *Volcanic Intrusions :*

Contemporaneous with the tectonic movements alluded to above, are a number of igneous outbursts occuring in the district in form of dykes or as flows of lavas generally of conical shape.

The distribution and extension of these outbursts are shown on the 1 : 100,000 geological map, accompaning the present text.

The dykes and lavas flows occasionally occupy the crestal parts of minor flexures and had slight metamorphic effects on the adjacent limestones or the sandstones of the country rock.

Petrographical Description by Y. Anwar.

At locality B, the limestone is cut by a number of dykes which had transformed it at the contacts into dark greenish rock. In hand specimen the dyke rock is dark grey in colour and of fine grained texture. In thin section it is found to be an olivine basalt and is seen to contain, in order of abundance, olivine, plagioclase felspar, pyroxene and ore.

The olivine is colourless except for alterations along borders and cracks into chlorite. It has an optic angle about 80° and negative sign indicating a fyalite content of about 20 %.

The plagioclase forms elongated lath shaped plates, mostly fresh, which may aggregate in groups with subparallel orientation. They show sharp outlines specially when they come in contact with the pyroxene. According to maximum symmetrical extinction angle determination the plagioclase is a basic labradorite with about 68 to 70 % An. Zoning is slightly developed. The dominant twinning is on albite and carlsbad laws.

The pyroxene is pail pinkish in colour and feebly pleochroic. It forms mostly rounded grains which may be isolated or in groups. Sometimes it is also seen enclosed between the plagioclase laths indicating a relatively later period of crystallisation. From optic axial determination the pyroxene is a diopsidic augite.

The dykes show chilled margins against the limestone. In thin section the rock is seen to be formed of olivine or its pseudomorphs, small laths of plagioclase and few crystals of pyroxene in a groundmass most of it is glass. In the latter microlites of plagioclase and iron ore could be identified with difficulty.

At locality B_3 there occurs a lava flow in the sandstone. Minerallogically the rock is of the same composition as the dyke rock of the previous locality. The sandstone in contact is transformed into a purplish red coloured rock. In thin section it could be seen that glassy material from the lava flow forms the matrix for the constituents of the sandstone. It is most likely that the glassy material represents part of the lava which was squeezed into the granular spaces of the sandstone.

The lava flows at the localities B_2 and B_5 are also olivine basalts, but are of slightly coarser grain size.

The lava flow at locality B_4 is a plagioclase porphyritic andesite. In thin section it is seen that labradorite (about 68 % an.) is the only porphyritic constituent. The groundmass consists of andesine (An. $_{47}$) 7 % as laths and iron ore with interstestial glass and chloritic material.

From the above descriptions and comparison with other volcanic intrusions from other localities to the north (Sadik) it seems most likely that both dykes and lava flows are genetically related being of the same magmatic cycle of Tertiary age. A generalisation cannot however be made as to the petrographical characteristics of the Tertiary Volcanicity in Egypt until a detailed study of this important epoch is made.

3. *Geological history of the District :*

The early history of this district takes us back to the days of the deposition of the Pre-Carboniferous Nubian series. The base of this series is not visible in the district but possibly it rests unconformable on the eroded surfaces of the igneous and metamorphic complex, as is the case with the Sinai Lower Carboniferous Sandstones.

The sea depositing these sandstones became deeper as time marched on and the Carboniferous limestones, clays, and marls were then deposited. Shallow water or even continental conditions followed this Carboniferous limestone, depositing the Inter-Carboniferous Nubian series and the fossil wood layer.

The shoaling of the sea continued after that, and in the southern parts of the district thick series of sandstones were deposited all through the ages till the Senonian sediments were reached. In the northern parts of the district, this shoaling was interrupted however, for a short interval during which the sea deepened to receive the first fossiliferous Jurassic layers, the clays and then the limestones. From field observations this Jurassic transgression reached till Lat. 29° 16′, but it

is possible that future investigations may reveal its extension further south.

This Jurassic sea must had been in connection with the Jurassic Tethys arm which deposited contemporaneous sediments over Khashm el Galala, Ras el Abd, Wadi Am Lug, Sinai and Western Europe.

Following on this short lived Jurassic, the unfossiliferous Nubian sandstones were deposited again from a long lived shallow sea which stretched over the whole area till the Cenomanian period of submergence is reached. This deposited the green marls with *Hemiaster cubicus, Ostrea africana* and *O. flabellata* conformably over the Jurassic-Cenomanian Nubian series.

The consequences of the Cenomanian transgression in the Northern Galala is not the scope of the present work, but from what shows in the literature of this plateau, dolomitic limestones and chalky beds, of the Upper Cretaceous, were deposited over these Cenomanian marls, to be followed by the Eocene to the top.

From the later part of the Eocene the district was part of the gradual upward movement which reached its climax in the Late Oligocene-Early Miocene times, and which arched the whole of the Gulf area into a huge anticline with its axis running N.E.-S.W., the two limbs of the anticline being in the west of the Gulf district and in Western Sinai. That it is why I believe that it is highly probable that Jurassic rocks which are found in the present area, have their continuation on the other side of the Gulf in Western Sinai, not far from the Carboniferous area of Om Bogma. The discovery of Jurassic rocks in that area will be awaited with much interest.

Lastly the domal uplifts, observed in many places in Wadi Araba and near Abou Darag, and which were synchronous with the great arching mentioned above, were responsible, together with the erosion by the Pleistocene high rain-fall, for the present configuration of this district, and were accompanied by volcanic activities which showed on the surface as dykes or lava-flows.

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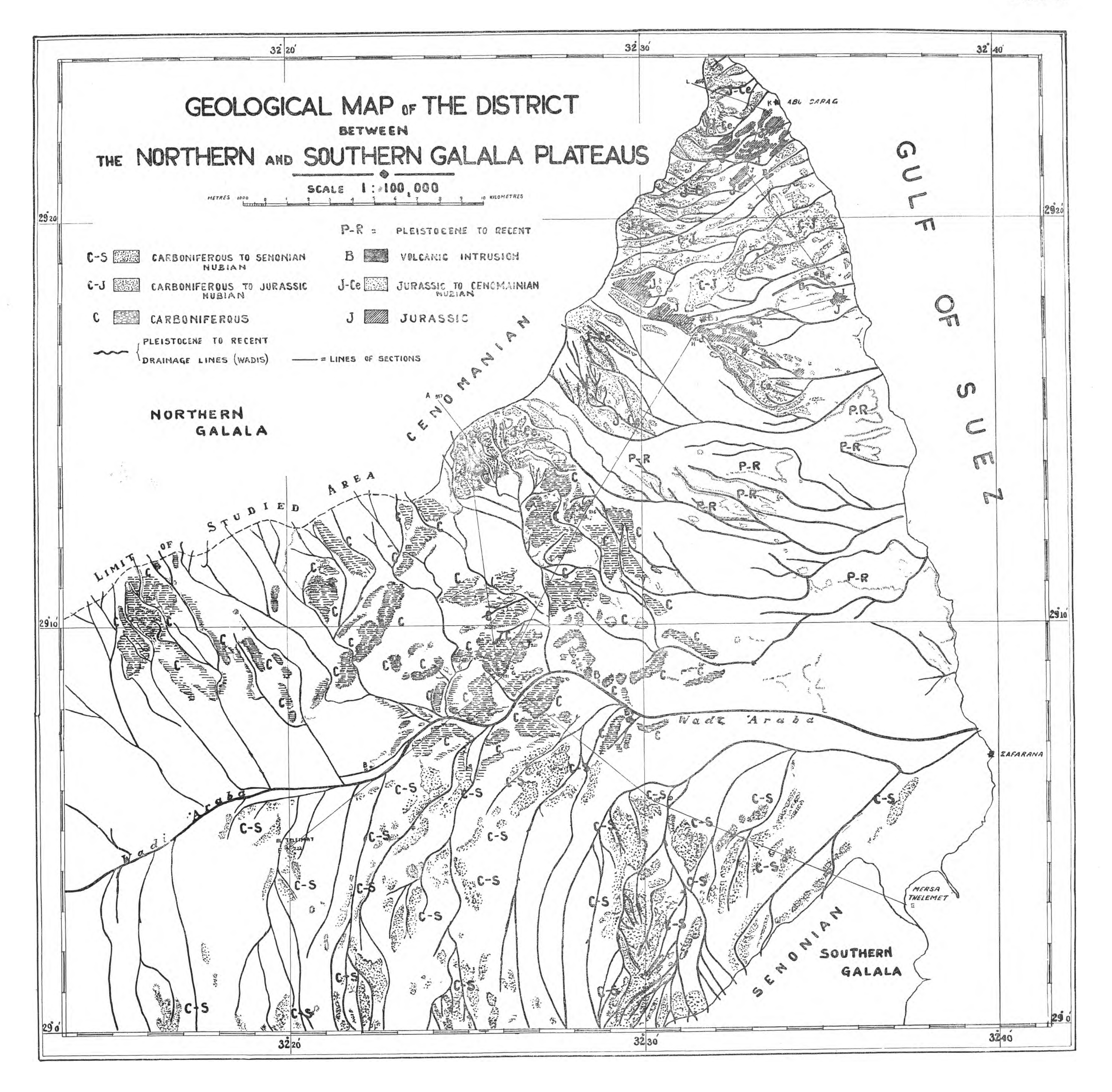
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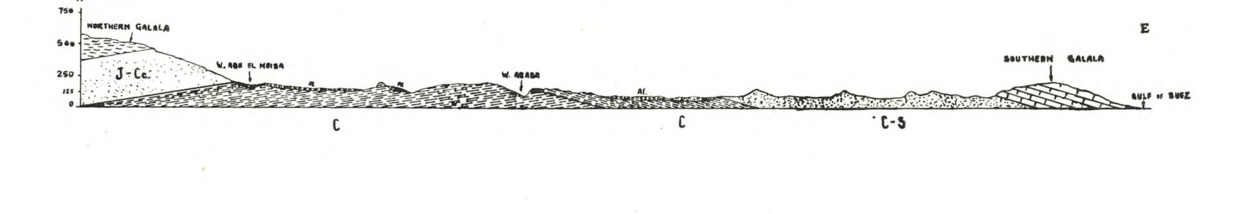
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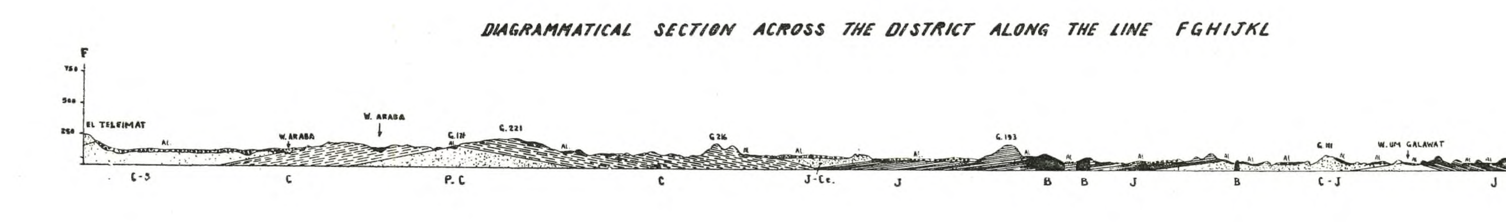
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GEOLOGICAL MAP OF THE DISTRICT
BETWEEN
THE NORTHERN AND SOUTHERN GALALA PLATEAUS
SCALE 1 : 100,000
METRES KILOMETRES
P-R = PLEISTOCENE TO RECENT
C-S CARBONIFEROUS TO SENONIAN NUBIAN
B VOLCANIC INTRUSION
C-J CARBONIFEROUS TO JURASSIC NUBIAN
J-Ce JURASSIC TO CENOMAINIAN NUBIAN
C CARBONIFEROUS
J JURASSIC
PLEISTOCENE TO RECENT DRAINAGE LINES (WADIS)
= LINES OF SECTIONS
NORTHERN GALALA
LIMIT OF STUDIED AREA
CENOMANIAN
GULF OF SUEZ
ABU DARAG
Wadi Araba
ZAFARANA
MERSA THELEMET
SENONIAN
SOUTHERN GALALA
32°20'
32°30'
32°40'
29°20'
29°10'
29°0'

DIAGRAMMATICAL SECTION ACROSS THE DISTRICT ALONG THE LINE ABCDE



DIAGRAMMATICAL SECTION ACROSS THE DISTRICT ALONG THE LINE FGHIJKL



J	Jurassic	Al.	Alluvium
C-S	Carboniferous to Senonian Nubian	B	Volcanic intrusion
C-J	Carboniferous to Jurassic Nubian		Senonian
C	Carboniferous		Cenomanian
P.C	Pre-Carboniferous Nubian	J-Ce.	Jurassic to Cenomanian Nubian

Scales:

Horizontal : 1 : 100,000

Vertical : 1 : 25,000 1 m/m = 25 M.

N.B. : Scale, before reduction for publication

THE EFFECT OF ETHYLENE ON STOMATA OF PELARGONIUM ZONALE [1]

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Introduction.

The effect of ethylene gas upon respiration and ripening of fruits is well known from the work of Denny (1924), Davis and Church (1931), Regeimbal, Vacha and Harvey (1927), and others. Denny (1924) found that the gas, even in a concentration of one part per million of air, increased the respiration of green lemons. Also, Davis and Church reported that treatment with ethylene stimulated the respiration of Japanese persimmons. Regeimbal and his co-workers reported that on treating ripening bananas with one part of ethylene to a thousand parts of air for 15 to 20 minutes the respiration was doubled or trebled within a few minutes after which the rate fell to a value lower than normal. It was assumed that the high initial increase might have been due either to the increase of oxidation or to increase in the permeability of the membranes, allowing the diffusion outward of CO_2 already in the cells. They also found that the sugar content of the treated bananas was increased while the starch content was proportionately decreased. So the activity of diastatic enzymes in the hydrolytic direction as well as respiratory enzymes was apparently increased by the treatment with ethylene.

Guthrie (1931) found that the P.H. value of the expressed juice of potatoes was increased by treatment with ethylene. Harvey (1927)

(1) Communication présentée en séance du 1er mars 1954.

considered that the effect of the ethylene upon the ripening process of fruits was to activate the enzymes which digested starch to sugar or oxidized acids and tannins.

Other investigators, like Davis and Church (1931), consider that ethylene affects the general metabolism of the plant.

There does not seem to be any previous work on the effect of ethylene upon the stomatal behaviour of plants. If the ethylene has an effect on diastatic activity, it may have an effect on the opening of the stomata, which may be the cause of increasing respiration as a result of allowing the outward diffusion of CO_2.

Experimental.

Pelargonium zonale was chosen for the present work. The leaf of the plant is homobaric, as pointed out by Heath (1941), as far as any individual sector enclosed by two main veins is concerned. Experiments performed by Williams (1948) showed that the two groups of stomata of two areas separated by a main vein can be regarded as reacting completely independently of each other.

Stomatal resistance to viscous flow of air was estimated at intervals of fifteen minutes by means of the resistance porometer devised by Gregory and Pearse (1934) shown in diagram (fig. 1). Both manometres were read with horizontal microscopes and were filled with a light hydrocarbon which gave a rapid response and was free from sticking.

The porometer cup was a glass one with an inlet and outlet. One of these is lateral and the other is a tube sealed into the end of the cup and projecting into it, ending just below the surface of the leaf, as shown in fig. 1. The cup was attached to the leaf by means of a gelatine washer. To obtain an air-tight joint, the cup was clamped to a perspex plate between which and the washer the leaf was placed. Before an experiment was to be set up the gelatine washer was coated with a mixture of beeswax and stopcock grease.

The apparatus consisted of two aspirators A and E, containing air of known CO_2 content, and the other ethylene gas. The rates of flow were controlled by two needle valves N_1 and N_2, and measured by flowmeters

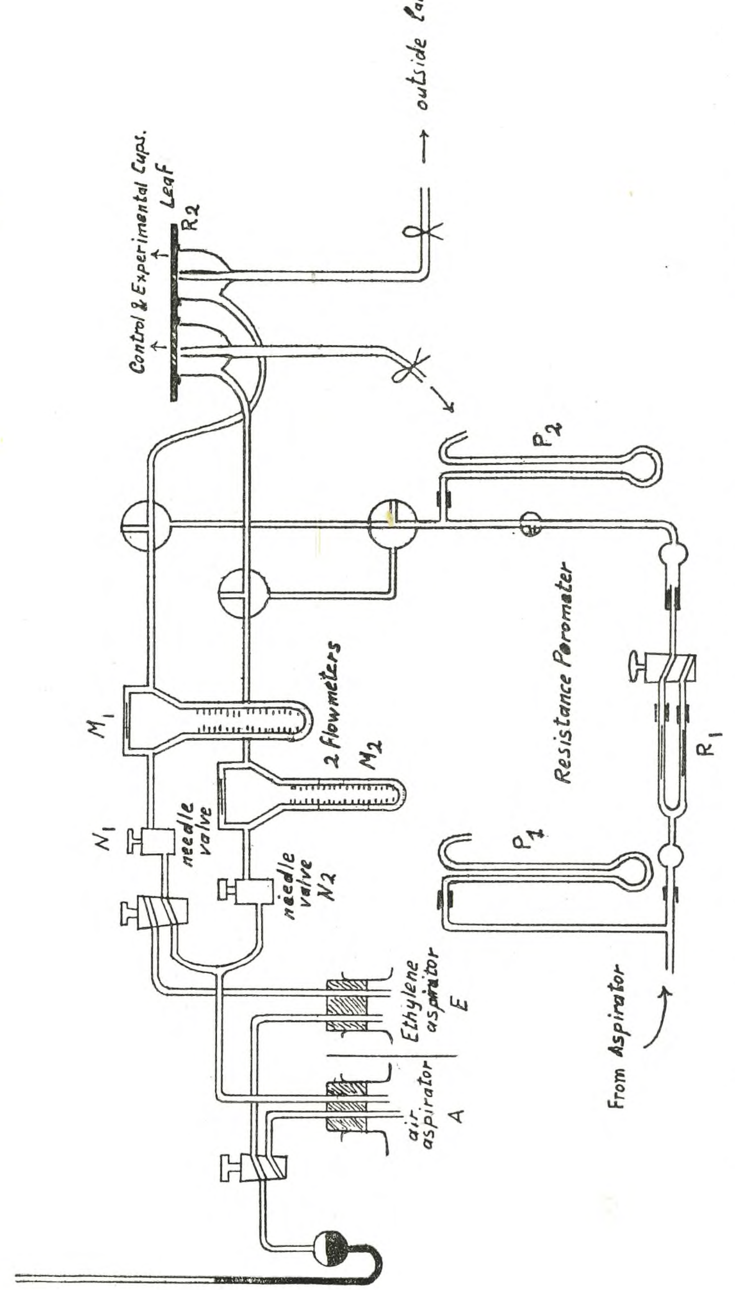


Fig. 1.—Apparatus : A & E are two aspirators, N_1 & N_2 are two needle valves, M_1 & M_2 are two flowmeters.

M_1 and M_2. In some experiments one porometer cup was used, but in the others two cups on the same leaf were used. One of these was swept by air throughout the whole experiment (Control cup), while the other was swept either by air or by air containing ethylene (experimental cup), as the case may be. Taps were so arranged that when a porometer reading of one cup was to be taken the exit tube of the cup was closed and the air or ethylene-air was passing at the same rate over the leaf in the other cup. Also by the aid of these taps and the screw valves, streams of ethylene-air or ethylene-free air could be alternated at the same rate of flow. The outlet of the experimental cup was connected to the outside of the lab., thus preventing contamination of laboratory air with the ethylene gas coming from the cup.

The experimental technique was to follow the stomatal movement under constant light and constant rate of air flow (2 litres per hour) with the resistance porometer at intervals of fifteen minutes until an equilibrium was reached and maintained for at least thirty minutes (2 successive readings). The air containing ethylene was now allowed to pass into one of the cups, but not the other, for one hour, and changes in stomatal opening in both cups were recorded. The air containing ethylene was now replaced by ordinary air for another hour and changes in stomatal opening were again recorded. Sometimes treatment with air containing ethylene was repeated a second time. Two concentrations of ethylene were used, viz. 1 % and 0.1 %.

In some experiments air containing ethylene was passed over the leaf in the experimental cup from the very beginning of the experiment until equilibrium was attained, when it was replaced by ordinary air for an hour and then air containing ethylene was allowed to pass for another hour.

Experiments with two porometer cups attached to the same leaf and using ordinary air throughout the experiment were done in order to see whether the stomatal movement of both areas enclosed in the two cups was synchronous or not.

During a porometer reading air was drawn through the leaf R_2 into a porometer cup by means of a constant pressure aspirator giving a pressure P_1, one of the standard capillary resistances R_1 being placed in series with the leaf resistance R_2, *i.e.* between the cup and aspirator. A paraffin manometer P_2 measures the pressure drop $(P_1 - P_2)$ across the leaf R_2, and a second manometer P_1 measures the total pressure drop $(P_1 - P_3)$ across $R_2 + R_1$ So $R_2 = \frac{P_2}{P_1 - P_2} - R_1$. The leaf resistances R_2 are plotted against time in each experiment.

RESULTS

The following are some experiments from many showing the same results.

Experiments n°s 1 and 2. Double-cup experiments using air throughout in both cups (tables 1 and 2, fig. 2). Fig. 2 shows that stomata of both cups responded to light nearly to the same extent and remained open till about noon. Stomata of both cups showed little closure in the afternoon, probably due to diurnal rhythm (Gregory and Pearse, 1934 & 1937). The two curves ran almost parallel. This shows that stomata of both sides of the leaf surface behave similarly toward light and an air stream of the same strength and velocity, respectively.

Experiments n°s 3 and 4. Double cup experiments using 0.1 % ethylene (tables 3 and 4, fig. 3). In these experiments air was used from the beginning until equilibrium was attained. Ethylene was then introduced into the experimental cup for one hour, and no change in the resistance of stomata to air flow was observed. When ethylene was replaced by air, stomatal resistance remained the same.

Experiments n°s 5 and 6. Double cup experiments using 0.1 % ethylene (tables 5 and 6, fig. 4). Here in these two experiments ethylene was introduced into the experimental cup from the beginning of the experiment the moment light was set in. The figures show that the 0.1 % ethylene had no effect on the stomata of Pelargonium and the stomata opened quite normally like the other stomata in the control cup. When ethylene air was replaced by ordinary air in the experimental cup, no change in the resistance of stomata to air flow was observed.

Experiments n°s 7 and 8. Double cup experiments using 1 % ethylene (tables 7 and 8, fig. 5). It is clear from fig. 5 that when ethylene was

applied to the experimental cup stomata of this cup as well as stomata of the control (which was supplied with air) tended to close. When ethylene was replaced by ordinary air, the stomata of both cups opened, but not to the same extent as before. When ethylene was let to pass once more in experiment n° 8, stomata of both cups closed once more.

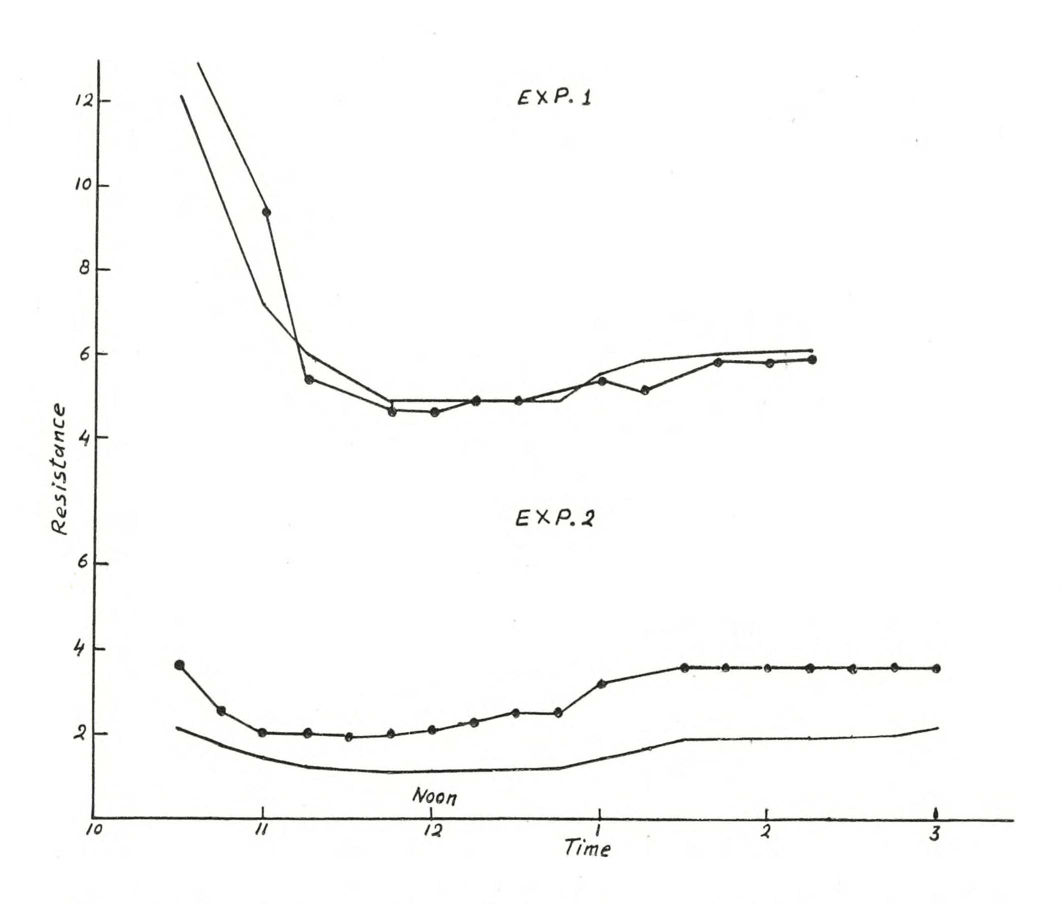


Fig. 2.—Experiments 1 and 2, showing the behaviour of stomata of both sides of Pelargonium leaf under light and air flow.

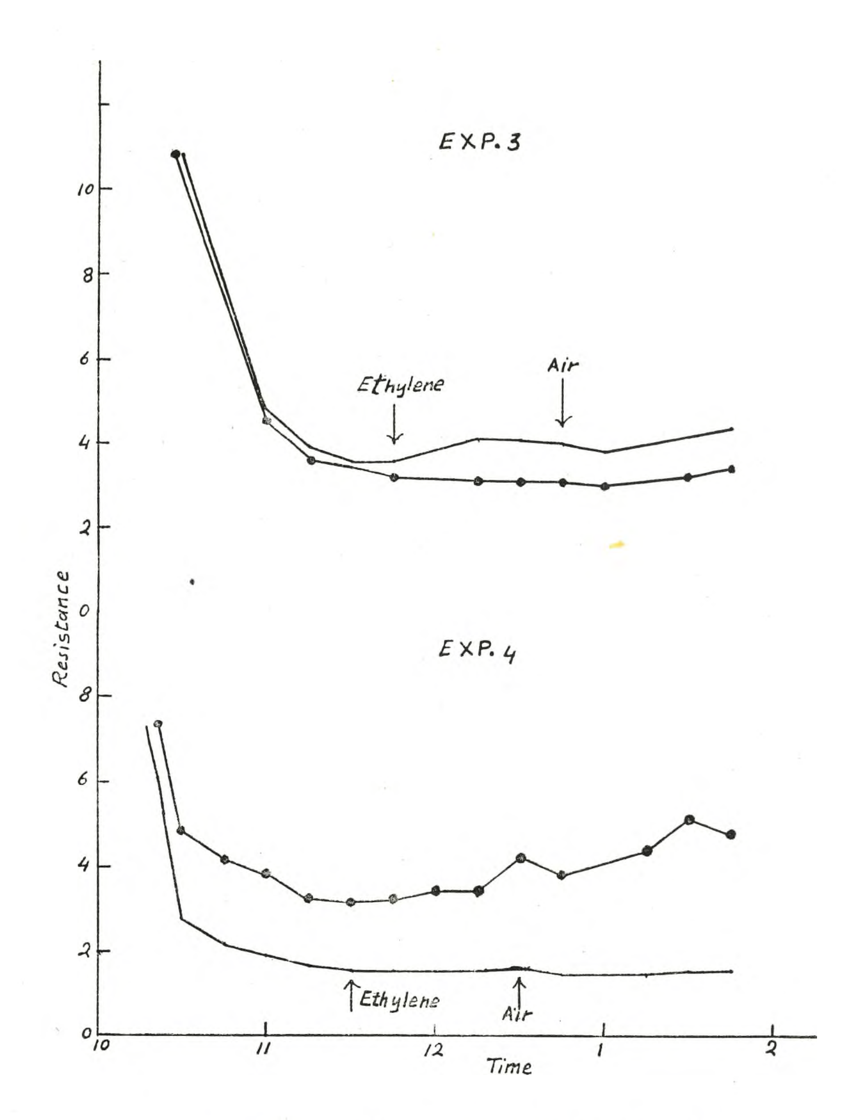


Fig. 3.—Experiments 3 and 4, showing the effect of 0.1 % ethylene on the stomata of Pelargonium leaf.

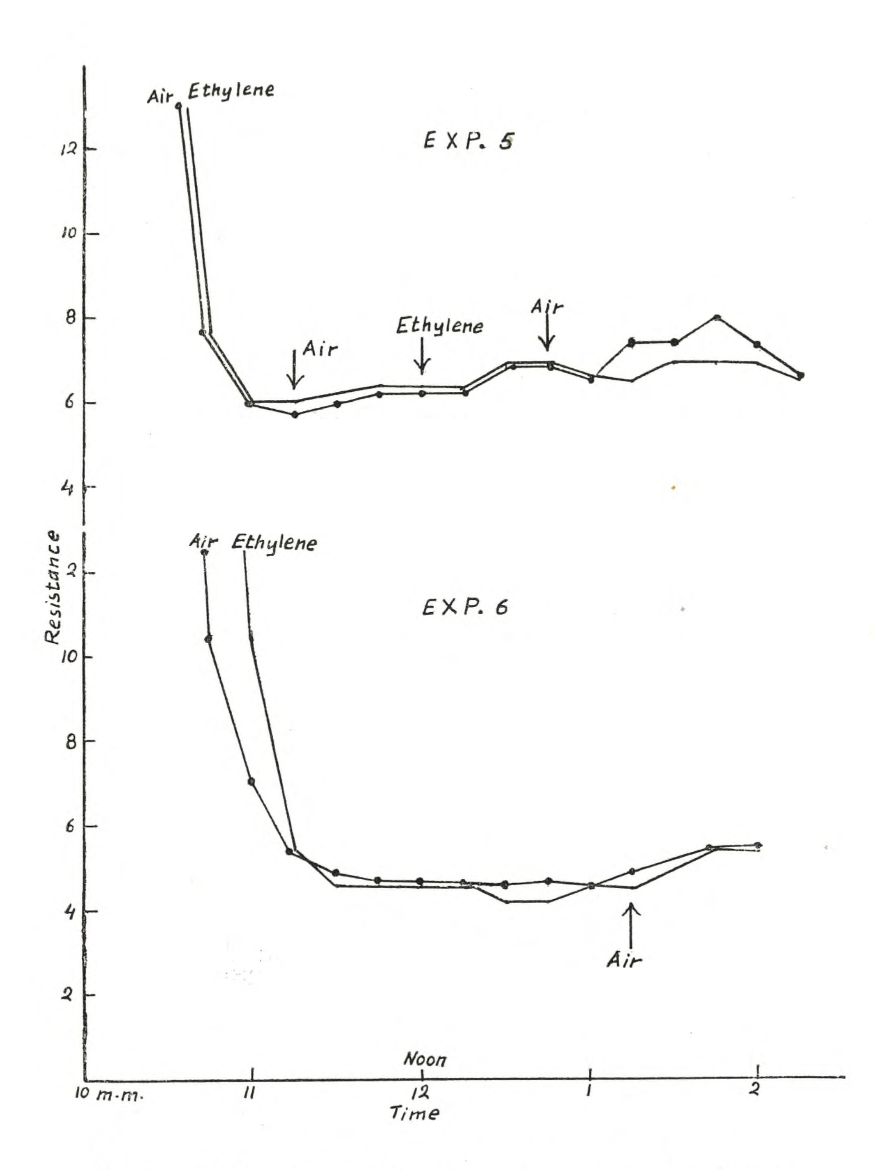


Fig. 4.—Experiments 5 and 6, showing the effect of 0.1 % ethylene on the stomata of Pelargonium leaf.

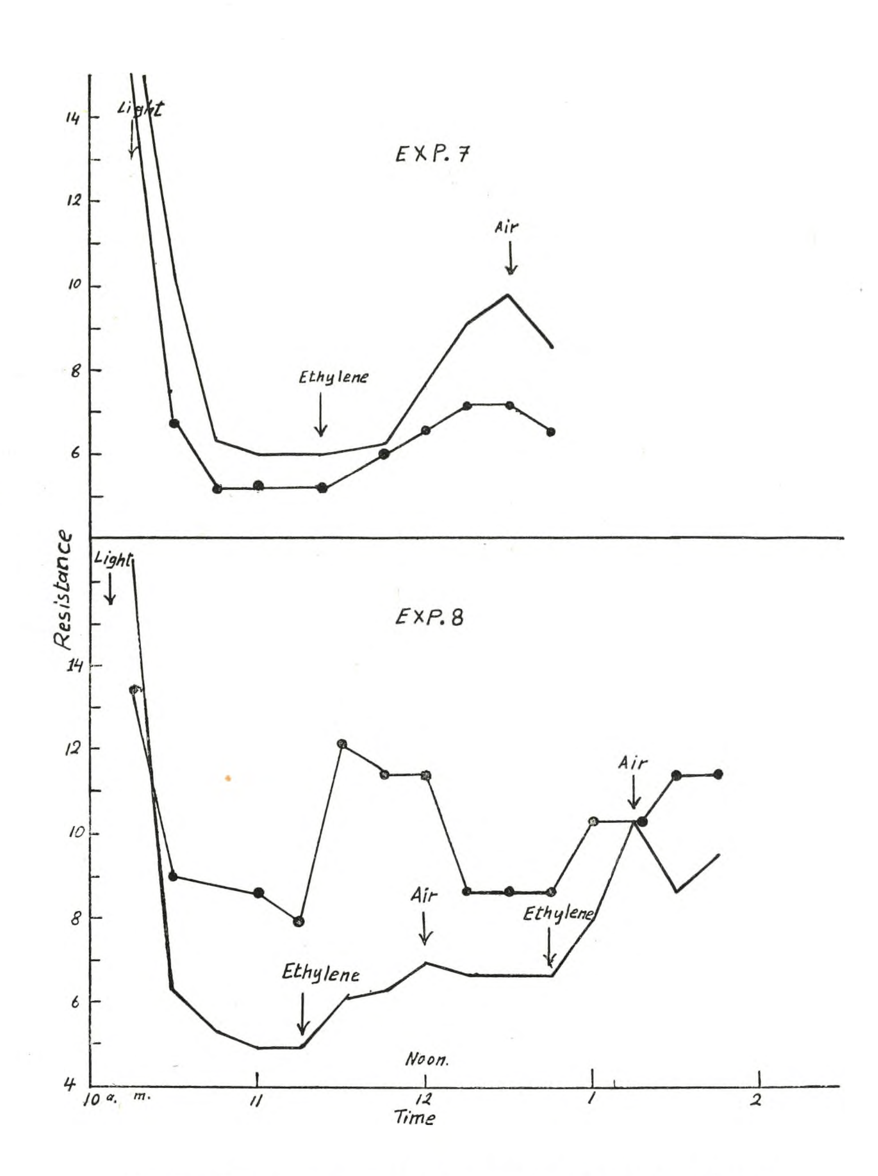


Fig. 5.—Experiments 7 and 8, showing the effect of 1 % ethylene on the stomata of Pelargonium leaf.

Experiments n°s 9 and 10. Single cup experiments using 1 % ethylene (tables 9 and 10, fig. 6). Fig 6 shows that stomatal resistance to air flow increased as a result of using ethylene-air stream, and this resistance decreased when ordinary air was used instead. The effect of ethylene on stomata was greater in Exp. 10 than in Exp. 9.

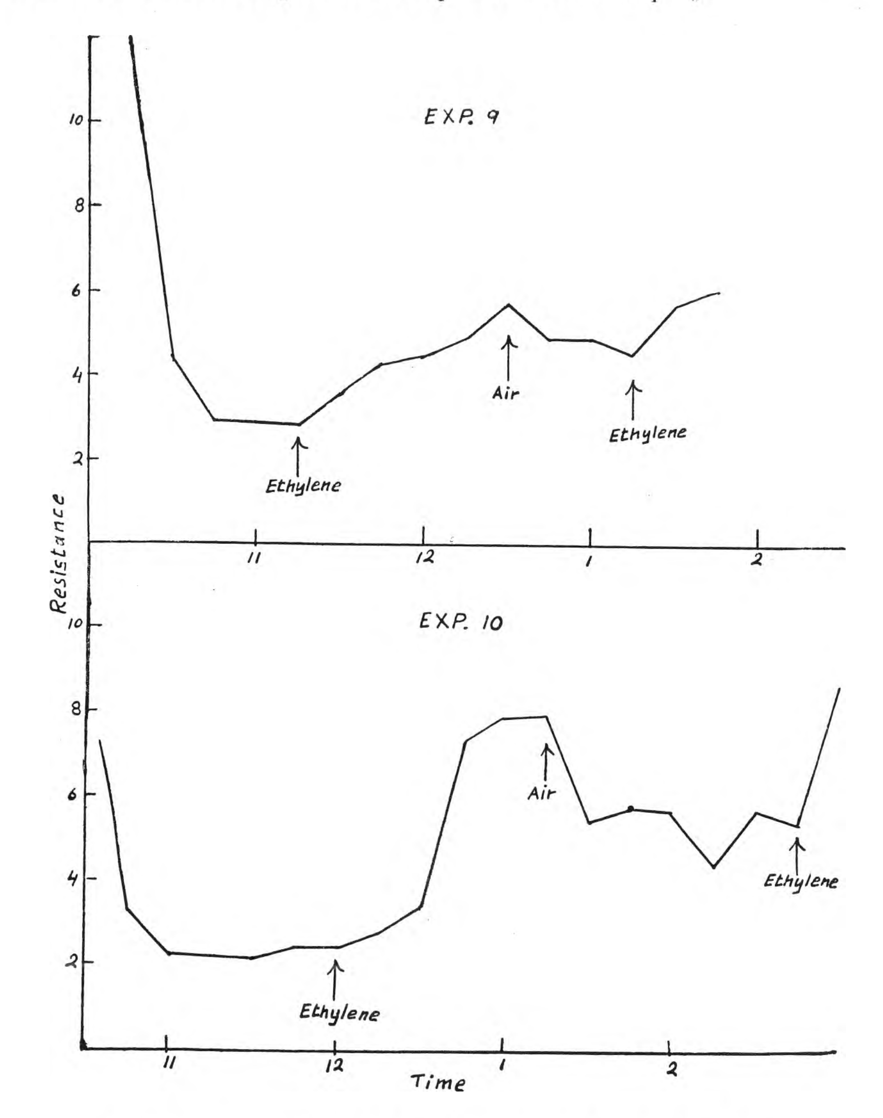


Fig. 6.—Experiments 9 and 10, showing the effect of 1 % ethylene on the stomata of Pelargonium leaf.

Table 1

EXPERIMENT 1.

Time	Condit'n	R_1 Cup n° 1	R_1 Cup n° 2
10.25 am.	D. L.	10.8	25.4
10.35 am.	D. L.	12.12	16.8
10.37 am.	Light	—	—
11.00 am.	»	7.2	9.45
11.15 am.	»	5.88	5.40
11.45 am.	»	4.92	4.68
12.00 noon.	»	4.92	4.68
12.15 pm.	»	4.92	4.92
12.30 pm.	»	4.92	4.92
1.00 pm.	»	5.64	5.4
1.15 pm.	»	5.88	5.28
1.40 pm.	»	6.0	5.88
2.00 pm.	»	6.12	5.76
2.15 pm.	»	6.12	5.88

Table 2

EXPERIMENT 2.

Time	Condit'n	R_2 Cup n° 1	R_2 Cup n° 2
10.30 am.	Light	2.16	3.6
10.45 am.	»	1.7	2.52
11.00 am.	»	1.44	2.04
11.15 am.	»	1.2	2.04
11.45 am.	»	1.1	1.88
12.00 noon.	»	1.16	2.04
12.15 pm.	»	1.2	2.16
12.30 pm.	»	1.2	2.32
12.45 pm.	»	1.2	2.52
1.00 pm.	»	1.4	3.24
1.30 pm.	»	1.7	3.6
1.45 pm.	»	1.77	3.6
2.00 pm.	»	1.88	3.6
2.15 pm.	»	1.88	3.6
2.45 pm.	»	2.00	3.6
3.00 pm.	»	2.2	3.6

Table 3 — 0.1 % Ethylene — Table 4

EXPERIMENT 3.

Time	Cup n° 1 Cond'n	Cup n° 1 R_2 Resis.	Cup n° 2 Cond'n	Cup n° 2 R_2 Resis.
10.30	Light	10.8	Light	10.8
11.00	Air	4.8	Air	4.56
11.15	»	3.96	»	3.6
11.30	»	3.6	»	3.48
11.45	»	3.6	»	3.24
11.45	Ethylene		»	
12.15	»	4.08	»	3.12
12.30	»	4.08	»	3.12
12.45	»	3.96	»	3.12
12.45	Air		»	
1.00	»	3.84	»	3.0
1.30	»	4.2	»	3.24
1.45	»	4.4	»	3.48

EXPERIMENT 4.

Time	Cup n° 1 Cond'n	Cup n° 1 R_2 Resis.	Cup n° 2 Cond'n	Cup n° 2 R_2 Resis.
10.10	Light	20.4	Light	20.4
10.10	Air		Air	
10.30	»	2.76	»	4.8
10.45	»	2.16	»	4.2
11.00	»	1.92	»	3.84
11.15	»	1.68	»	3.24
11.30		1.56	»	3.12
11.30	Ethylene			
11.45	»	1.56	»	3.24
12.00	»	1.56	»	3.48
12.15	»	1.56	»	3.48
12.30	Air			4.2
12.30	»			
1.45	»	1.44	»	3.84
1.15	»	1.44	»	4.32
1.30	»	1.56	»	5.16
1.45	»	1.56	»	4.8

0.1 % Ethylene

Table 5 — Table 6

Time	Experiment 5. Cup n° 1 Cond'n	Cup n° 1 R_2 Resis.	Cup n° 2 Cond'n	Cup n° 2 R_2 Resis.	Time	Experiment 6. Cup n° 1 Cond'n	Cup n° 1 R_2 Resis.	Cup n° 2 Cond'n	Cup n° 2 R_2 Resis.
10.00	—	43.2	—	27.6	10.05	Air		Air	
10.00	Ethylene	—	Air		10.10	»	43.2	»	43.2
10.15	»	22.8	»	15.6	10.20	»	43.2	»	43.2
10.30	»	16.8	»	15.6	10.30	»	43.2	»	27.6
10.32	Light		Light		10.30	Ethylene		»	
10.45	»	7.68	»	7.68	10.45	»	21.0	»	10.32
11.00	»	6.0	»	6.0	11.00	Light	10.32	Light	7.0
11.15	»	6.0	»	5.7	11.0	»		»	
11.15	Air		»		11.15	»	5.4	»	5.4
11.30	»	6.2	»	6.0	11.30	»	4.56	»	4.8
11.45	»	6.36	»	6.2	11.45	»	4.56	»	4.68
12noon	»	6.36	»	6.2	12noon		4.56	»	4.68
12.05	Ethylene		»		12.15	»	4.68	»	4.56
12.15	»	6.36	»	6.36	12.30	»	4.2	»	4.56
12.30	»	6.9	»	6.9	12.45	»	4.2	»	4.68
12.45	»	6.9	»	6.9	1.00	»	4.68	»	4.56
12.45	Air		»		1.15	»	4.56	»	4.92
1.00	»	6.6	»	6.6	1.15	Air		»	
1.15	»	6.48	»	7.4	1.45	»	5.4	»	5.4
1.30	»	6.9	»	7.4	2.00	»	5.4	»	5.4
1.45	»	6.9	»	8.04					
2.00	»	6.9	»	7.4					
2.15	»	6.9	»	6.6					

1 % Ethylene

Table 7 — Table 8

Time	Experiment 7. Cup n° 1 Cond'n	Cup n° 1 R_2 Resis.	Cup n° 2 Cond'n	Cup n° 2 R_2 Resis.	Time	Experiment 8. Cup n° 1 Cond'n	Cup n° 1 R_2 Resis.	Cup n° 2 Cond'n	Cup n° 2 R_2 Resis.
					10.00		64.8		51.8
10.10	Light	36.8	Light	24.0	10.05	Light		Light	
12.12	Air		Air		10.20	Air	16.5	Air	13.4
10.30	»	10.3	»	6.84	10.35	»	6.36	»	9.0
10.45	»	6.36	»	5.28	10.50	»	5.28	»	10.3
11.00	»	6.0	»	5.28	11.05	»	4.92	»	8.64
11.20	»	6.0	»	5.28	11.20	»	4.92	»	7.92
11.25	Ethylene		»		11.22	Ethylene		»	
11.45	»	6.0	»	6.0	11.35	»	6.0	»	12.1
12.00	»	7.68	»	6.6	11.50	»	7.2	»	11.4
12.20	»	9.24	»	7.2	12.05	»	7.9	»	11.4
12.40	»	9.84	»	7.2	12.20	»	6.6	»	8.64
12.42	Air		»		12.22	Air		»	
1.00	»	8.64	»	6.6	12.35	»	6.6	»	8.64
					12.50	»	6.6	»	8.64
					12.52	Ethylene		»	
					1.05	»	7.9	»	10.3
					1.20	»	10.3	»	10.3
					1.22	Air		»	
					1.35	»	8.64	»	11.4
					1.50	»	9.49	»	11.4

See page 282 tables 9 and 10

1 % ETHYLENE

TABLE 9 TABLE 10

EXPERIMENT 9.			EXPERIMENT 10.		
Time	Condition	Resistance R_2	Time	Condition	Resistance R_2
10.10	Light	86.76	10.10	Light	52.08
10.05	»	86.6	10.15	»	64.8
10.05	Air		10.25	»	64.8
10.30	»	4.32	10.25	Air	
10.45	»	2.88	10.40	»	7.32
11.00	»	2.83	10.50	»	3.24
11.10	»	2.82	11.00	»	2.28
11.15	»	2.82	11.30	»	2.16
11.15	Ethylene		11.45	»	2.4
11.30	»	3.6	11.50	»	2.4
11.45	»	4.32	12.00	»	2.4
12.00	»	4.44	12.00	Ethylene	
12.15	»	4.92	12.15	»	2.76
12.30	»	5.76	12.30	»	3.36
12.30	Air		12.45	»	7.32
12.45	»	4.92	1.00	»	7.92
1.00	»	4.9	1.15	»	7.92
1.10	»	4.56	1.15	Air	
1.10	Ethylene		1.35	»	5.46
1.25	»	5.7	1.45	»	5.76
1.45	»	6.0	2.00	»	5.64
			2.15	»	4.4
			2.30	»	5.7
			2.45	»	5.4
			2.45	Ethylene	
			3.00	»	8.4
			3.15	»	10.0

DISCUSSION.

As we have seen from works mentioned in the introduction that ethylene increases respiration and favours hydrolysis of starch when present in very low concentration even as low as one part per million. The results of the present work showed that 0.1 % ethylene had no effect on the movement of stomata of Pelargonium Zonale even if the gas is allowed to pass into the porometer cup from the very beginning of the experiment, and we have seen that stomata open quite normally as the stomata of the control cup under atmospheric air. That only 1 % ethylene caused closure of stomata leads to the discussion of the possible cause of such closure by such high concentration of ethylene and not by 0.1 %.

Closure of stomata under light may be brought about by condensation of starch and decrease in osmotic pressure or change of P. H. value of guard cells towards acid side or as a result of shock effect or other causes not concerned in this discussion.

As we know that ethylene favours hydrolysis of starch as proved by Regeimbal and his Co-workers, we expect that stomata will open under the effect of this gas assuming that the same concentration producing the same hydrolytic effect on starch, but the contrary took place in the present work and stomata closed. This means that stomata of Pelargonium either open and close with no relation to the starch Sugar balance or the ethylene at such concentration did not affect this balance in these experiments. The first assumption may be right if we consider the work of Heath (1949) on the same plant. He concluded that factors other than light have much bigger effects than light itself upon the starch content of the guard cells and that light responses of the stomata may occur apparently independently of changes in stomatal starch contents. In other words as far as the responses to light is concerned the evidence for a Sugar starch hypothesis is not convincing.

As to the change of P. H. value in the guard cells this may have been the cause of this closure as we have seen that ethylene increases respiration i.e. production of CO_2 and this will decrease the P. H. value of

the guard cells and may be the cause of closure of stomata. That ethylene affects the P. H. value of the cells is proved by Guthrie (1931). This favours the hypothesis put forward by Sayre (1923, 1926) and confirmed by Scarth (1929, 1932) that the effect of light is to bring about a decrease in the acidity of the guard cells. This decrease increases the hydrolytic activity of diastase, starch is converted into sugar the O.P. in the guard cells rises and the stomata open. This was criticised by Heath (1949) and others like Hanes (1940) and the conclusion reached is that if the light response of the stomata is a fact due to P. H. change there is little evidence that it acts through the hydrolysis of starch (Heath 1949).

The third possibility is that this closure is probably a result of shock effect similar to the mechanical or heat shock investigated by Williams (1948, 1949) on the same plant. Williams found that this shock effect producing closure of stomata is brought about simply by a draught of hot air over the leaf from the small flame used. This view is supported by the fact that stomata of both cups (control and experimental) were equally affected by ethylene passing into the experimental cup only. This could be explained by transmission of the shock produced in the experimental cup across the leaf which was proved by Williams in case of heat shock. He suggests the production of a toxin or wound hormone which is transmitted to the rest of the leaf. Such a toxin may be the cause of closure of stomata probably through raising the respiration of guard cells.

Yet considerable work remains to be done on other plants if the problem of the effect of ethylene on stomata is to be fully elucidated.

Summary.

1. The stomata of both sides of leaf of Pelargonium Zonale behave similarly toward light and air flow.

2. 0.1 % ethylene has no effect on stomatal behaviour of Pelargonium Zonale.

3. 1 % ethylene has a closing effect on the stomata of the same plant.

4. The stomata of the control cup were affected by the ethylene-air stream passing into the experimental cup.

5. It is suggested that this closure is probably due to shock effect produced by such a high concentration of ethylene.

Acknowledgment.

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ESSAI SUR LE PRINCIPE DE LA MASSO-DYNAMIQUE [1]

PAR

GASTON FLEURI

Avant d'aborder ce sujet, j'ai d'abord un devoir à remplir : c'est de remercier toutes les personnes qui ont bien voulu m'aider dans cette étude.

Depuis la dernière guerre mondiale je suis complètement aveugle. Je ne puis ni lire ni écrire, on comprend donc finalement que des aides m'ont été indispensables pour établir cette étude.

C'est avant tout ma précieuse auxiliaire, Madame Niquet Milliand qui, non seulement a eu la patience d'écrire jusqu'au bout ce que je lui dictais, mais encore a esquissé les nombreux graphiques dont j'avais besoin.

C'est ensuite mon petit fils, Michel Fleuri, ingénieur des Travaux Publics, qui a exécuté et complété ces graphiques et s'est chargé de vérifier tous mes calculs. Sa femme l'a secondé en tapant à la machine les parties qui ne contenaient ni graphiques ni formules algébriques.

PRÉLIMINAIRES

J'ai toujours considéré les principes de Masso-Dynamique comme composés de deux parties :

1° La variation de la masse ;

2° Le fait que cette masse est de l'énergie.

[1] Cet exposé est une introduction à l'article paru dans le *Bulletin de l'Institut d'Égypte,* t. XXXV, p. 281-308.

La première partie à elle seule me paraît suffisante pour distinguer dans le cas qui nous occupe la mécanique d'Einstein de l'ancienne mécanique. Je me suis donc demandé si il ne me serait pas possible de reconstituer la Masso-Dynamique d'Einstein en m'appuyant seulement sur cette première partie. Expliquons-nous clairement.

Je voulais retrouver le travail du grand mathématicien en me servant seulement des hypothèses suivantes : La masse croît avec sa vitesse, à chaque vitesse correspond une masse et réciproquement à chaque masse une vitesse. Je suis parvenu à mes fins en considérant deux triangles rectangles variables dont l'un est caractérisé par son hypoténuse « c» (vitesse de la lumière) et l'autre par son côté de l'angle droit m_0, l'hypothénuse de ce dernier triangle est variable et se compose un par un des obliques de la perpendiculaire m_0. Je me sers donc des notations suivantes : « v» une vitesse, « c» la vitesse de la lumière, « m» une masse et « m_0» la valeur de cette masse quand sa vitesse est nulle. Je considère ensemble les angles aigus de ces deux triangles qui varient de o à $\frac{\pi}{2}$.

Pour la valeur zéro de ces angles un des côtés du premier triangle est zéro tandis que la masse dans le second triangle est m_0. Le premier triangle représente par ses côtés toutes les vitesses depuis o jusqu'à c, tandis que le second triangle représente toutes les masses depuis m_0. jusqu'à l'infini.

Pour satisfaire ma seconde hypothèse il suffit que les angles aigus de ces deux triangles restent constamment égaux ou autrement dit que les triangles que j'ai appelés fondamentaux restent semblables et j'ai de plus montré que de quelque façon qu'on exprime la similitude de ces triangles fondamentaux on obtient toujours la même équation : celle qui donne la relation entre la masse et sa vitesse et que j'ai appelée équation ou formule fondamentale; on peut écrire cette formule :

$$\frac{m}{m_0} = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

elle résulte de la similitude des triangles fondamentaux.

C'est Monsieur Leprince Ringuet professeur à l'école polytechnique et membre de l'Académie des Sciences qui m'a communiqué cette formule avant même que j'ai commencé cette étude et c'est en étudiant la graphique de cette formule que j'ai naturellement rencontré les triangles fondamentaux et que j'en ai compris toute l'importance.

Energie massique.

En faisant cette découverte de la masso-énergie, Einstein a introduit dans la mécanique une énergie nouvelle.

Comme cette énergie n'a pas encore reçu de nom je me permets de l'appeler : énergie massique.

L'énergie massique est tout simplement l'énergie de masse. Il faut faire très attention car nous possédions déjà une énergie de masse, mais c'est une énergie potentielle qui ne dépend que de la position de la masse et pas du tout de sa valeur intrinsèque, tandis que l'énergie massique dépend uniquement de la valeur intrinsèque de cette masse.

Je vais d'abord m'occuper de trouver la forme de l'énergie massique. Pour cela je partirai de la valeur énergétique de la masse m, c'est-à-dire de mc^2. J'ai montré plus tard comment on pouvait connaître à priori cette valeur énergétique mais je ne me servirai pas de cette démonstration ; il me suffira de prendre pour guide cette valeur énergétique et de démontrer plus tard que le résultat auquel j'arriverai est bien de l'énergie massique.

Revenons donc à l'expression mc^2, si la masse m est sans vitesse alors $m = m_0$ et l'expression précédente s'écrit $m_0 c^2$ et sous cette forme on voit clairement que c'est l'énergie de la masse m_0 et par conséquent un cas particulier d'énergie massique.

Si la masse m est en mouvement elle possède alors la vitesse v donnée par :

$$v^2 = c^2\left(1 - \frac{m_0^2}{m^2}\right)$$

La masse m contient alors l'énergie cinétique $\frac{1}{2} mv^2$ et c'est cette énergie qu'il faut retrancher de mc^2 pour obtenir l'énergie massique pure. Cette énergie se présente donc sous la forme :

$$mc^2 - \frac{1}{2} mv^2$$

Le résultat est bien de l'énergie massique. Pour le voir il suffit de remplacer v^2 par sa valeur dans la formule de cette énergie c'est-à-dire de calculer :

$$mc^2 - \tfrac{1}{2} mc^2 \left(1 - \frac{m_0^2}{m^2}\right)$$

ce qui donne :

$$\frac{m^2 + m_0^2}{2\, mc^2}\, c^2$$

et sous cette forme on voit bien qu'on a de l'énergie massique puisque c'est l'énergie de la masse :

$$\frac{m^2 + m_0^2}{2\, m}$$

Pour que la masse soit de l'énergie il faut que l'élément d'énergie massique puisse s'égaler à l'élément d'énergie générale.

L'élément d'énergie massique s'obtient facilement en remplaçant la masse m par son élément dans la première forme de cette énergie on trouve ainsi :

$$c^2\, dm - \tfrac{1}{2} dm\, v^2$$

Il s'agit maintenant d'obtenir l'élément d'énergie générale. Or, dans l'ancienne mécanique, la notation $\frac{1}{2}$ de mv^2 avait deux sens. Si v ne changeait pas de valeur $\frac{1}{2}$ de mv^2 était de l'énergie cinétique mais si $\frac{1}{2}$ de mv^2 était une fonction de la vitesse v cela était pris pour représenter l'énergie générale. Il n'y a pas lieu de changer cette façon de voir; mais comme dans la mécanique d'Einstein, la variation de vitesse entraîne la variation de la masse; la quantité $\frac{1}{2}$ de mv^2 n'est plus fonction de la vitesse v seule mais fonction à la fois de la vitesse v et de la masse m. Pour avoir l'élément d'énergie générale, il faut donc calculer la différentielle de $\frac{1}{2}$ de mv^2 comme celle d'un produit de facteur ou calculer :

$$\tfrac{1}{2}\,(m + dm)\,(v + dv)^2 - \tfrac{1}{2}\, m\, v^2$$

Suivant les principes de l'analyse infinitésimale c'est-à-dire en laissant de côté les infinitésimaux [1] de deuxième et de troisième ordre.

[1] D'ordre supérieur qui sont dans ce cas les infinitésimaux... de deuxième... etc.

Quel que soit le procédé qu'on emploie, on trouve toujours la même quantité :

$$m\, v\, dv + \tfrac{1}{2}\, dm\, v^2$$

Il faut donc, pour que la masse soit de l'énergie, vérifier l'égalité :

$$c^2\, dm - \tfrac{1}{2}\, m\, v^2 = m\, v\, dv + \tfrac{1}{2}\, dm\, v^2$$

Cette égalité est une équation différentielle. Réunissons les termes semblables et séparons les variables. Nous obtenons :

$$\frac{dm}{m} = \frac{v\, dv}{c^2 - v^2}$$

Le premier membre est la différentielle de log. m et nous obtiendrons également pour le second membre la différentielle d'un log. en multipliant ce second membre par :

$$(-\tfrac{1}{2})\,(-2) = 1$$

ce qui ne change pas sa valeur.

On obtient alors pour le second membre la différentielle de log. $(c^2 - v^2) - \frac{1}{2}$.

Il ne reste plus alors qu'à intégrer de o à v et de revenir des log. aux nombres. Ce qui donne :

$$\frac{m}{m_0} = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

c'est-à-dire la formule fondamentale dont nous avons démontré l'existence.

Dans le chapitre intitulé : «Un nouveau graphique», j'ai retrouvé la plupart de ces résultats d'une autre façon et, j'ai de plus, construit l'énergie massique à la place qu'elle doit occuper dans ce nouveau graphique.

J'ai joint à cette étude quelques notes que j'ai jugées utiles pour la compréhension de l'étude masse-énergie d'Einstein.

NOTA : *Comme Einstein n'a jamais parlé de nouvelle énergie je réclame la priorité pour l'introduction en mécanique de l'énergie massique.*

Et pour qu'il n'y ait pas d'erreur sur ce que j'entends par énergie massique, je donne de nouveau ici l'expression de cette nouvelle *énergie sous ses deux formes :*

$$m^{c2} - {}^{1}/_{2}\, mv^2 = \frac{m^2 + m_0^2}{2\, m}\, c^2$$

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القاهرة

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١٩٥٥